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AND ABSTRACT OF THE LITERATURE

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An Inquiry in Regard to the Cause of Spinners' Scrotal Cancer

A Study of the Lead Line, Arteriosclerosis, and Hypertension in 381 Lead Workers

The Comfort Zone for Men at Rest and Stripped to the Waist

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THE JOURNAL OF INDUSTRIAL HYGIENE

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AN INQUIRY IN REGARD TO THE CAUSE OF SPINNERS' SCROTAL CANCER*

JAMES ROBERTSON, M.B., D.P.H.

Medical Officer of Health, Darwen, England

INTRODUCTION

SINCE 1920 the attention of those engaged in cotton spinning has been directed toward the disease known as scrotal cancer because of its increased incidence among mule spinners. Anxiety among employers has also arisen since the judgment given in 1922 in a Lancashire county court in favor of a workman suffering from this disease. The judgment of the court was that, upon the evidence laid before it, the disease arose out of and in course of the employment. The evidence was to the effect that the mineral oil used to lubricate the mule is thrown off by the rotating spindles on to the faller shaft and the spinners' overalls. The friction of the shaft on the scrotum as the man leans over it, together with the irritation of the oil, was stated to be the cause of the disease (1).

This judgment was in full accord with what was then, and still is, the general opinion. It would appear to be founded on the fact that some cases of cancer have been reported among workmen employed in the processes of refining mineral oils, and among shale workers (2) (3) (4).

This question of spinners' scrotal cancer first arrested my attention in 1923 in the course of official visits to cotton mills. Observation caused me to doubt the prevailing opinion as to the cause of the disease. I commenced investigations which led me to express these doubts in my Annual Report for 1923 (5), and to advance a counter opinion. As a result of this Report I was asked to give evidence in June, 1925, before a special com-

*Received for publication Dec. 15, 1926.

mission appointed by the government, which I did accordingly.

At the commencement of my investigations I was met by two difficulties: First, there would appear to be nothing written or published on this disease in reference to spinners (in any medical journal) except one article by A. H. Southam and S. R. Wilson, of Manchester (6). Second, no definite information can be had from the local hospitals. Their records are very incomplete or not kept, and the death registers do not help much.

Starting with the definite statements made in Southam and Wilson's article (6), I divide my thesis into three main parts and a conclusion: (1) the faller shaft and the process of oiling; (2) the oil as found upon the overalls; (3) a suggested and more evident line of thought as to the cause of this disease; and (4) conclusions.

The Spinning Mule.—Before proceeding to detail the experiments which I have carried out, it would be useful at this stage to give a brief description of the spinning mule and its working.

The spinning mule consists of two main parts, the creel—which is fixed—and the carriage—which moves. The latter is all that we need consider. It is composed of the faller shaft and the bolster, both extending the whole length of the mule, anywhere from 30 to 40 yards. The faller shaft, a circular steel rod, stands 33 inches above the floor and carries the wire controlling the tension and direction of the threads during twisting and winding. The bolster is $6\frac{1}{2}$ inches to the inside of the faller shaft, and $4\frac{1}{2}$ inches below, and carries the spindles with the cops (see A in Fig. 1).

The carriage travels from and to the creel over a distance of 64 inches, its weight being taken by wheels running on rails on the floor. Its movement may be divided into three phases (see Fig. 2): (1) the movement from the creel occupying nine seconds, during which the cotton is drawn and twisted into thread, the spindles revolving at 9,000 revolutions a minute; (2) a rest of two and one-half seconds when a change of gear and action takes place; and (3) the return to the creel occupying three and one-half seconds, the thread twisted being now wound on the cops. The spindles are now rotating at only 180 to 200 revolutions a minute. The time for one complete movement, or "draw," as it is called, is therefore fifteen seconds.

Fixed to the creel, also about 33 inches above the floor, is a row of small rollers, running the whole length of the creel, called the delivery rollers, as they deliver the cotton from the bobbins to the cops to be spun. When a thread breaks, the spinner pieces the broken end directly to these delivery rollers.

Part I. The Faller Shaft and the Process of Oiling

The Spinner and the Faller Shaft.—During the outward movement of the carriage, the spinner leans over the faller shaft to piece together the ends of the threads which have broken in the twisting. He can only do so during the initial part of the movement; he cannot reach anywhere near 64 inches, as he must piece the broken

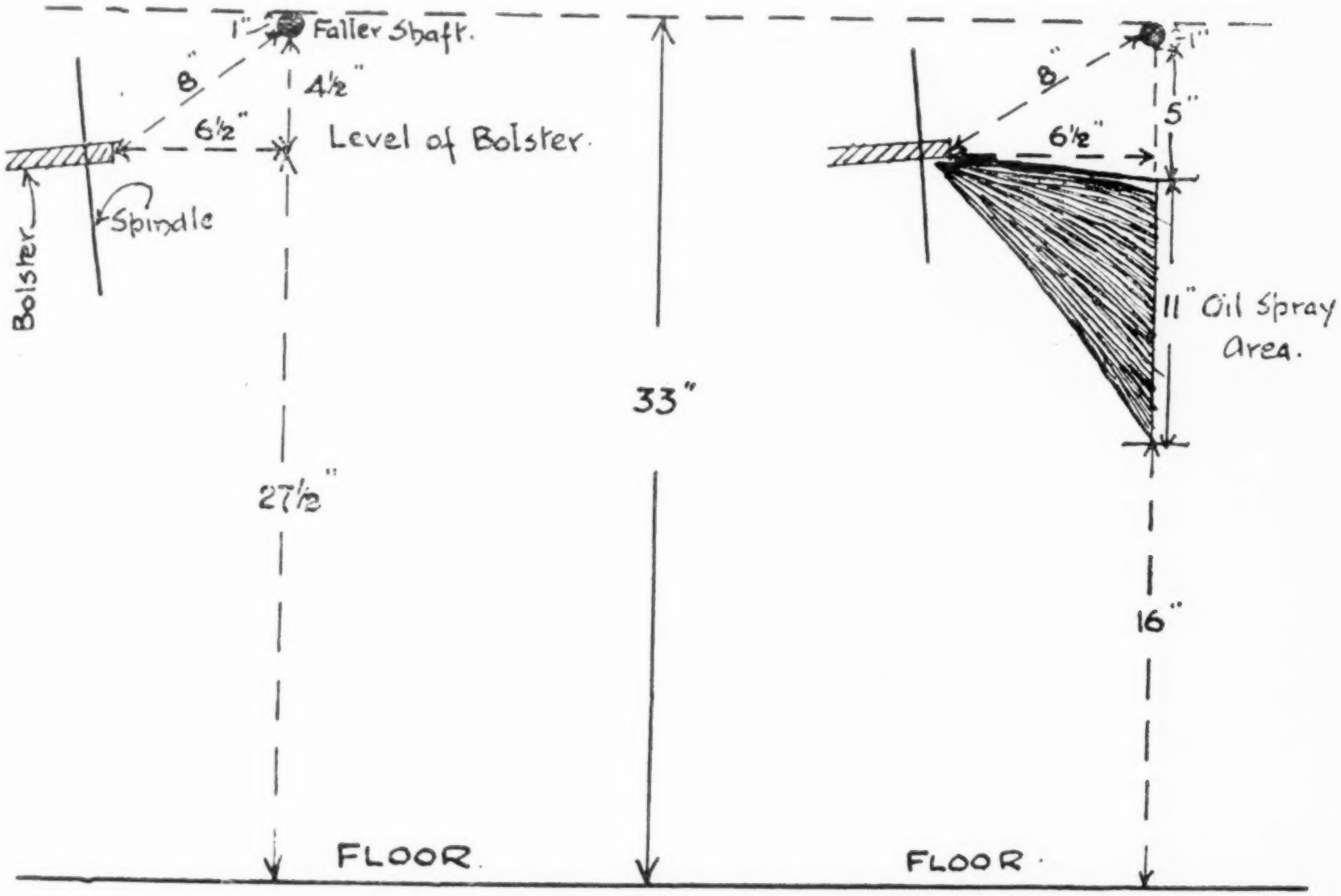

FIG. 1.—Diagram showing (A) relation of parts of spinning mule and (B) oil spray.

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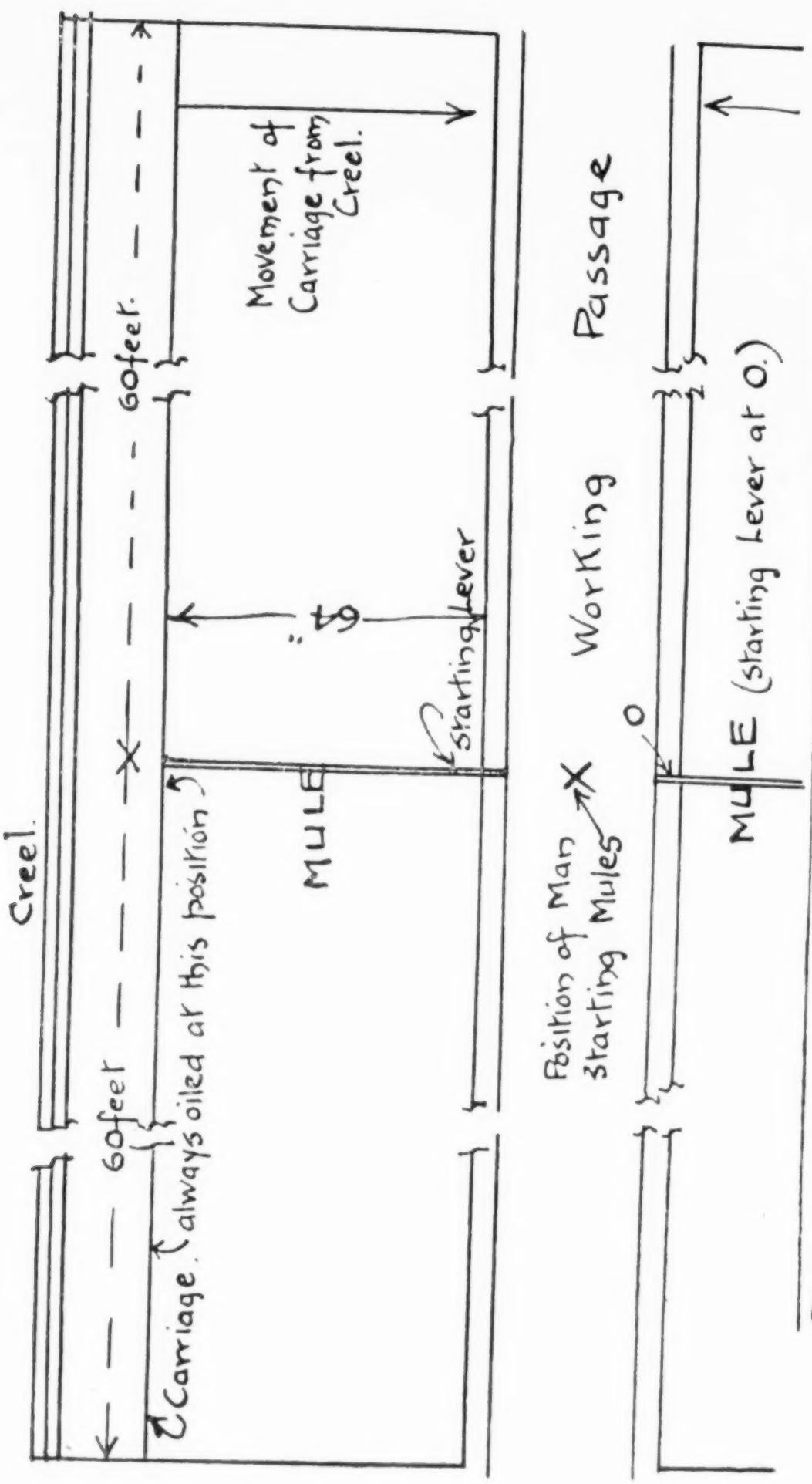

FIG. 2.—Diagram showing position of man operating mules.

nd directly to the delivery rollers ixed to the creel. Any threads missed

foot being thrown out behind as a counterbalance.

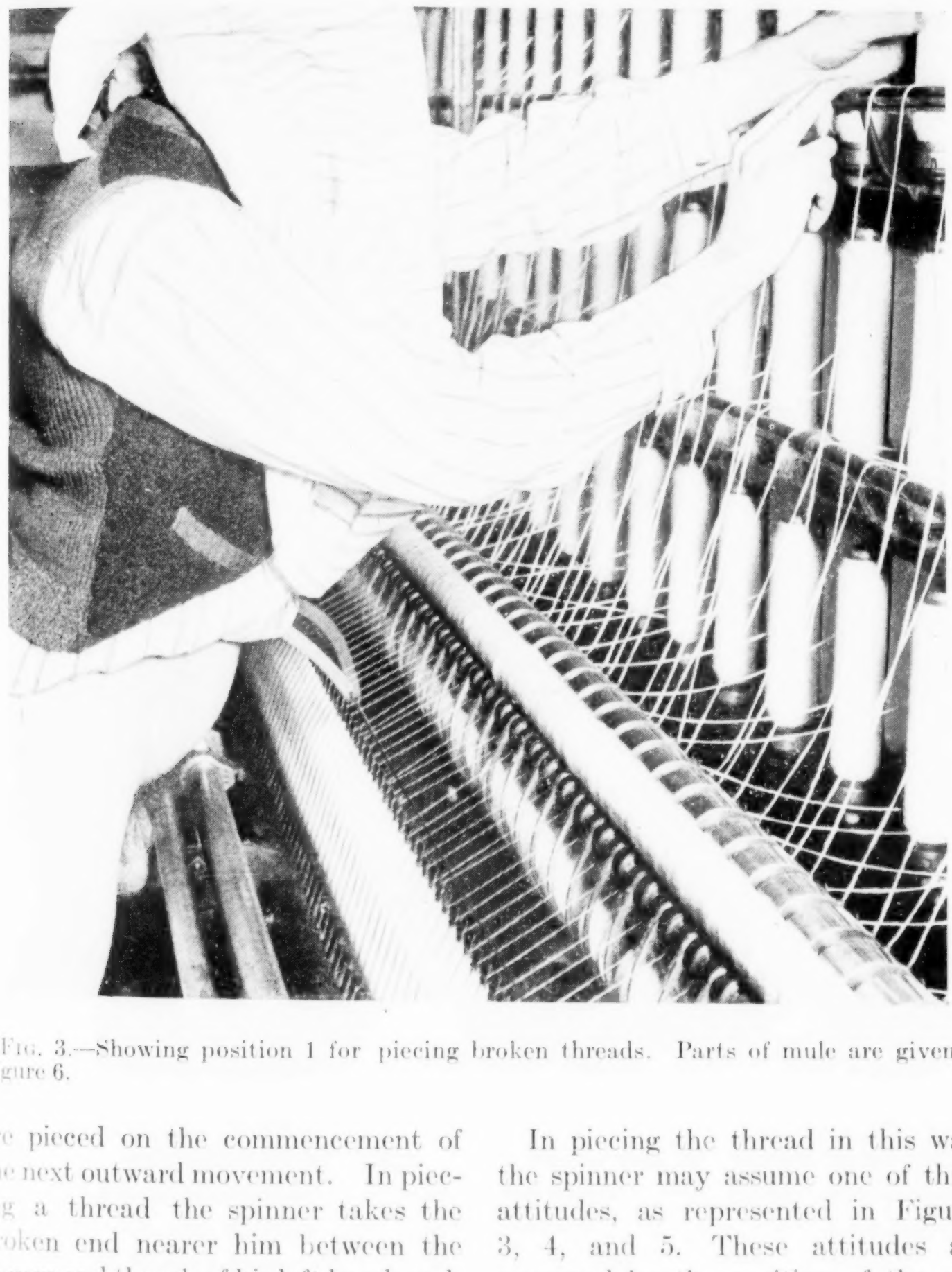

FIG. 3.—Showing position 1 for piecing broken threads. Parts of mule are given in Figure 6.

are pieced on the commencement of the next outward movement. In piecing a thread the spinner takes the broken end nearer him between the fingers and thumb of his left hand, and, standing somewhat sideways with his weight on his left foot, leans over and joins it to the other end on the delivery roller with a quick twist, his right

In piecing the thread in this way, the spinner may assume one of three attitudes, as represented in Figures 3, 4, and 5. These attitudes are governed by the position of the carriage with reference to the creel at the moment of piecing. The spinner shown in these figures was a man 5 feet, 8 inches in height; clearly his

scrotum is not, in any of the positions, in contact with the faller shaft. In

FIG. 4.—Showing position 2 for piecing broken threads. Parts of mule are given in Figure 6.

fact, in positions 1 and 2 the left testicle and its scrotal covering are $2\frac{1}{2}$ inches below the under edge of the faller shaft, and in position 3 the scrotum is $1\frac{3}{4}$ inches away from the shaft; yet this dependent scrotal area on its lower left medial aspect is the usual site of the epithelioma.

Since writing the foregoing, I have read an article by John Brown (7), of which the following is an extract under the heading "Protection:" "Where possible, until mules are suitably designed, employers should employ long-legged operatives." This, as a protection against the possible friction of the scrotum on the faller shaft, is obviously in complete disagreement with my measurements as given above.

I have watched these men closely when they have been at work, and while the spinner's attention has been fully occupied during the act of piec-

FIG. 5.—Showing position 3 for piecing broken threads. Parts of mule are given in Figure 6.

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FIG. 4.—Showing position 2 for piecing broken threads. Parts of mule are given in Figure 6.

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FIG. 5.—Showing position 3 for piecing broken threads. Parts of mule are given in Figure 6.

ing I have slipped my hand along the shaft and always found a space between it and the man. While his overalls, being loose, might touch the shaft, his body does not press against it; in any case, as he leans over somewhat on his left side, his left thigh is between his testicles and the shaft, and his testicles are below the shaft. A very small percentage of the men piece with their right hands, and these remarks apply equally to them.

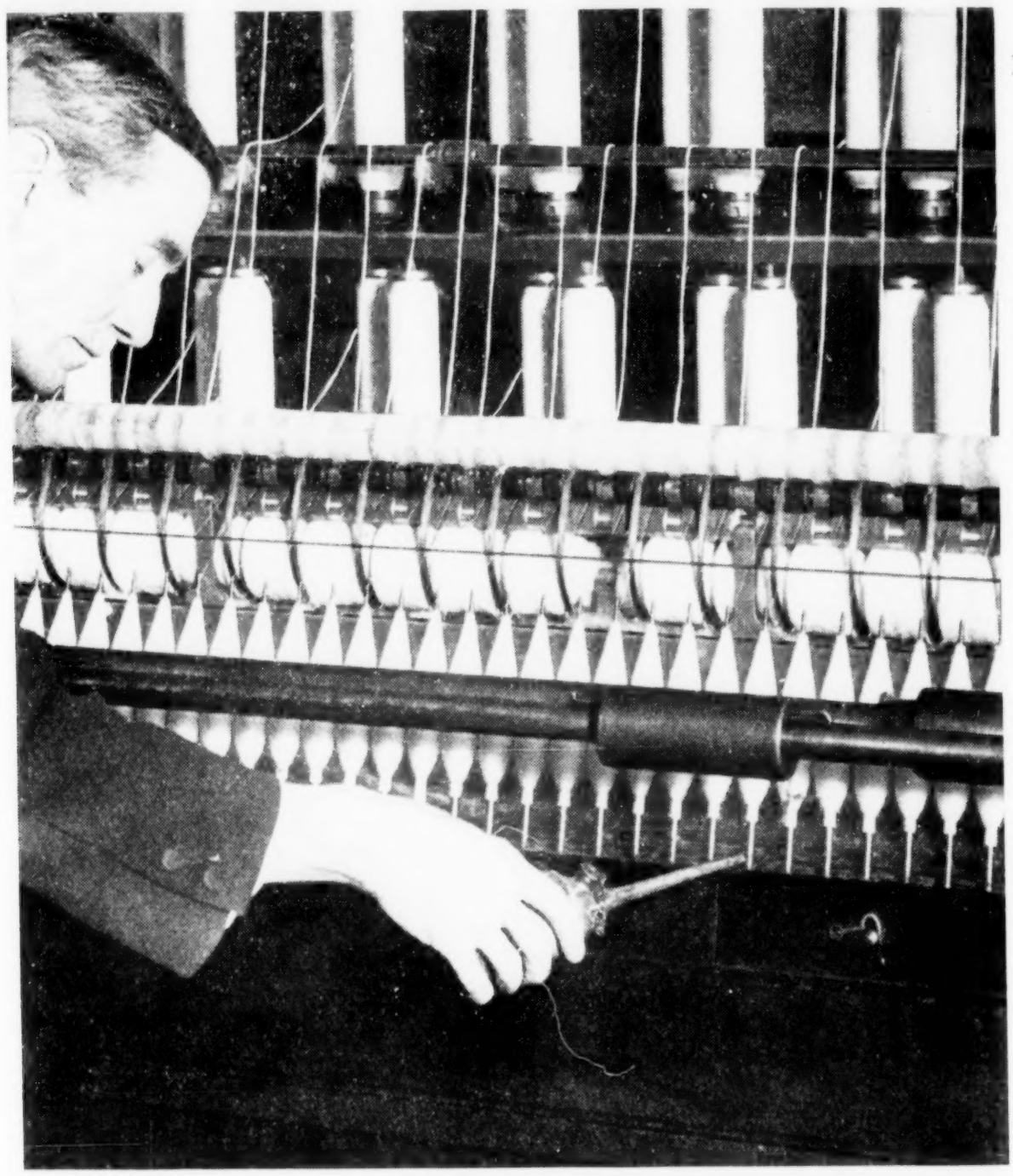

FIG. 6.—Oiling bolster; carriage door closed.
1 = bobbins on creel. 2 = delivery rollers on creel. 3 = faller shafts.
4 = spindles with cops. 5 = bolster. 6 = carriage door.

The spinner's movement is necessarily quick; he makes a dive across his machine. His overalls, the only garment that he wears, are quite loose; and his scrotum is more or less free to swing. The pressure, then, which was supposed to be exerted on his scrotum would not be pressure at all, but would be more in the nature of a blow. He may perform this movement 240 times in an hour. I cannot conceive of any man impinging his testicles 240 times an hour against a rigid steel rod. Yet this is prac-

ually what the present theory suggests.

The Oiling of the Bolster.—The bolster, as previously stated, is $6\frac{1}{2}$

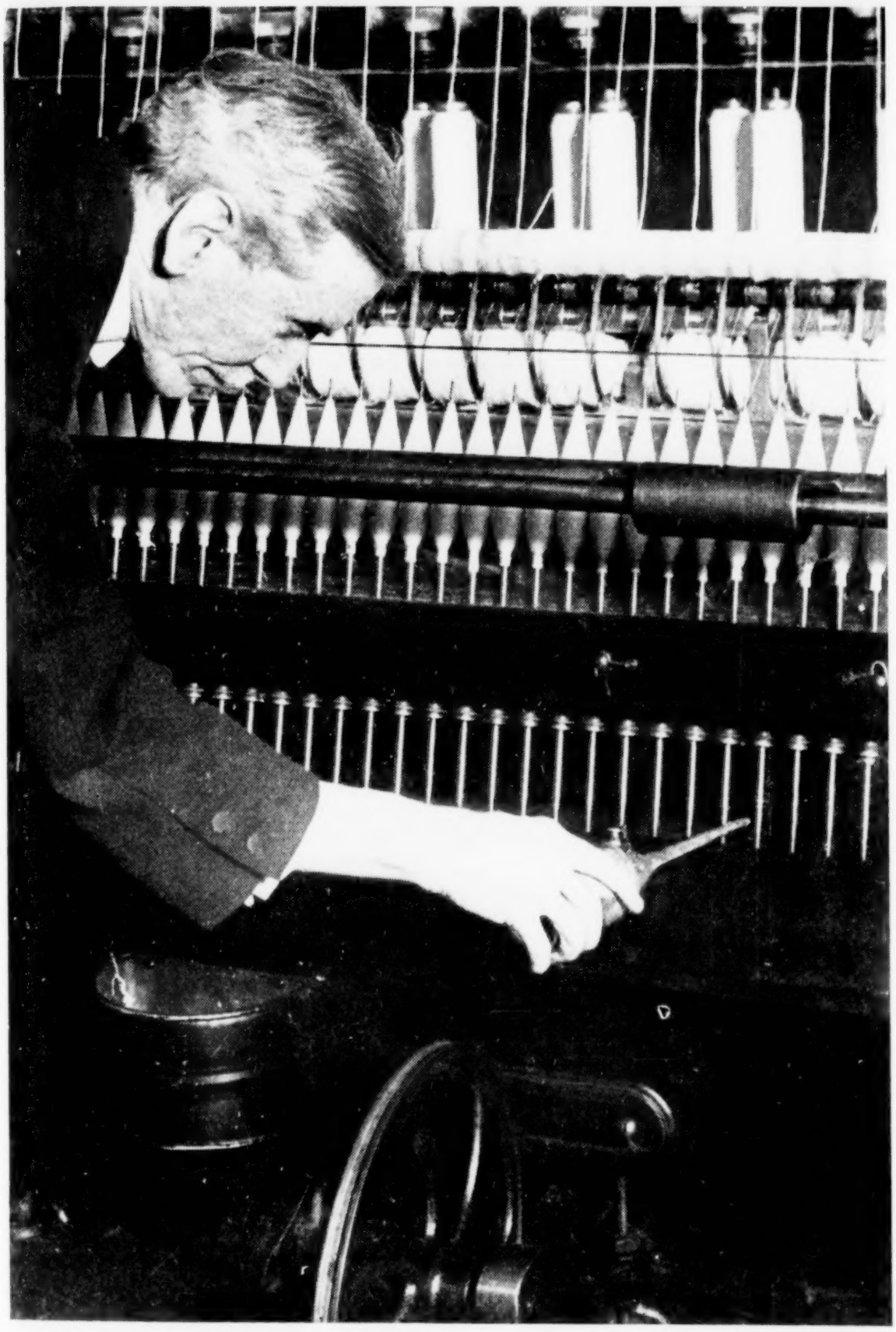

FIG. 7.—Oiling steps; carriage door open.

I conclude, therefore, that friction of the faller shaft on the lower end of the scrotum does not take place, and consequently has nothing whatever to do with the causation of spinners' scrotal cancer.

inches to the inner side of the faller shaft and $4\frac{1}{2}$ inches below. It is lined along its upper edge with brass having circular holes. The spindles pass through these holes, their bases resting in small cups known as steps.

These cups and the brass on the top of the bolster are the bearings of the spindles, and oil is applied to these two places in order to lessen friction (see Figs. 6 and 7). The cups are filled with oil once a week, but are shut off from the rest of the machine and from the worker by wooden doors, which are opened only during the process of oiling. Any oil which might reach the worker by spraying must come from the brass bearings on the top of the bolster. These are oiled twice a day, once in the morning before starting up, and again after the midday halt. The oiling is done before the mule is started and while the carriage is close to the creel. The spinner takes his long-spouted oil can, pours some oil on the floor to make sure that it is running clean, then, beginning at one end of the mule and walking along, allows a steady stream to run on to the brass lining where the spindles pass through. This oil soaks into the holes and passes down the spindles.

Although the diameter of the spindles is small, nevertheless, the centrifugal force which they exert while revolving at 9,000 revolutions a minute is bound to be considerable. Any oil, therefore, which remains on the spindles above their point of contact with the brass lining of the bolster will be thrown off in the form of a spray. When no oil is there, the spray will naturally cease. It is now necessary to determine the extent and the duration of this spray.

Experiments Showing Extent and Duration of Oil Spray from Bolster (see B in Fig. 1).—As Southam and Wilson (6) state in their article that the faller shaft is oily and sprayed by the oil thrown off from the spindles, I proceeded to experiment carefully with the machines immediately after oiling. All the experiments detailed were repeated several times in two cotton mills, and were also checked at the spinning mule in Blackburn Technical College.

My first three blotting paper experiments gave negative results. They were carried out as follows:

EXPERIMENTS 1 to 3.—For Experiment 1, I proceeded to mill No. 1, about 10:30 A.M., applied a full sheet of blotting paper (23 inches long by 17½ inches wide) to the faller shaft, and left it on the mule for five minutes—*i.e.*, twenty draws. For Experiments 2 and 3, this procedure was repeated at mill No. 2 at 3 P.M., and at the Technical College, respectively.

Result.—In all three experiments the blotters were found to be clean, and no oil was visible.

These three experiments demonstrate that no oil is thrown off during ordinary working. Examining faller shafts in several mills, I found them not only free from oil, but showing signs of actual rust.

EXPERIMENT 4.—Sheets of white blotting paper[1] were wrapped round the faller shaft, and the bolster was oiled. The mule was then started and left working for five minutes. The blotters were removed and examined at the end of this period.

Result.—No oil was visible, even under a magnifying glass; chemical test was negative to oil.

EXPERIMENT 5.—Blotting paper was fixed to the faller shaft, the several sheets hanging freely downward, as shown in Figure 8. A length of shaft of 23 inches was left, so that an intermediate or check experiment could be made. The bolster

[1] The sheets of blotting paper used in this and the subsequent experiments were each 12 inches long by 17½ inches wide.

oiled, and the mule was started and run for five minutes. The check blotter was

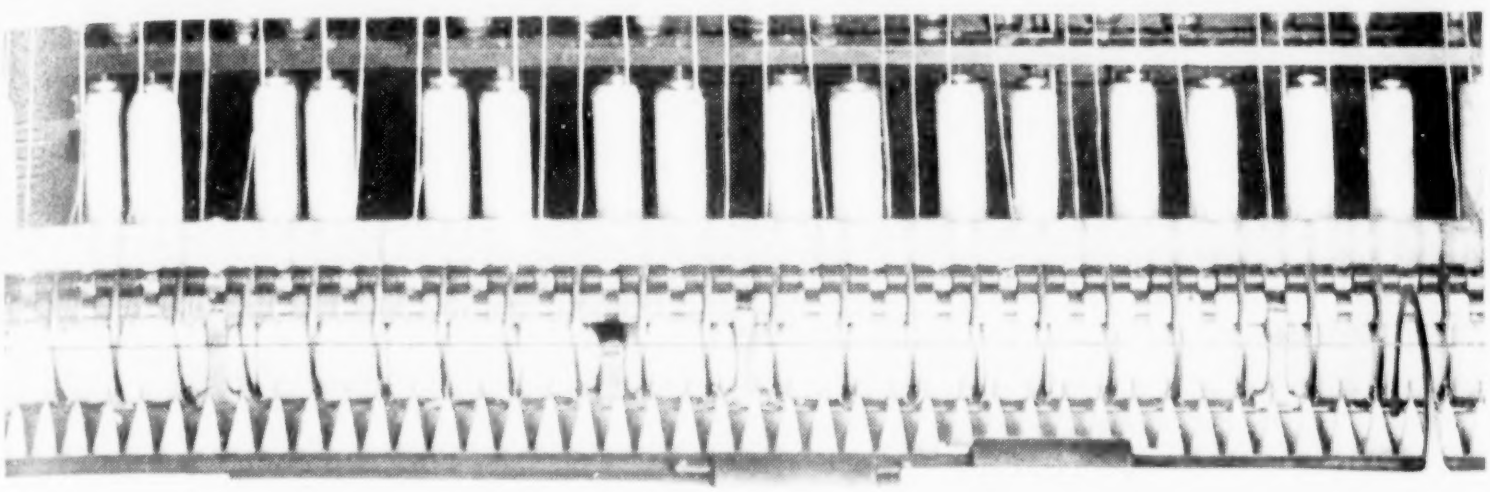

FIG. 8.—Showing blotting paper attached to faller shaft.

held to the shaft during the fourth and fifth minutes. The machine was stopped, and the fixed blotters were removed for examination.

Result.—Fixed blotters: (1) Oil was found distributed as a fine spray. (2) Small specks of dirt were distributed in the same manner as the oil. (3) There was a definite straight line of demarcation 5 inches below, and parallel to, the faller shaft. The greatest density was within 1½ inches of this line. Between this line and the shaft there was neither dirt nor oil. The oil and dirt spray rapidly thinned in a downward direction, its lowest point being about 11 inches below the line of demarcation. *Check blotter:* This was clean, showing neither oil nor dirt.

These two experiments prove conclusively that, while the spindles do spray, the faller shaft receives none of the oil, and that all the oil is off at the end of the first three minutes.

Figure 9 was taken to represent the oil spray as thrown off the bolster after oiling. In order to get such a photograph, it was necessary to use a dirty machine, to mix dirt deliberately in the oil, and to over-oil the machine. All the oil, even in this experiment, was thrown off in three seconds. The amount of oil extracted from the piece of blotting paper here represented was 0.1333 gm. A photograph could not be taken of a blotting paper result from ordinary working conditions; the oil distribution, however, was the same and the amount of oil thrown varied from 0.02 to 0.05 gm.

FIG. 9.—Photograph of blotting paper (12 inches long by 17½ inches wide) showing distribution of oil spray.

1 = line of attachment, represented by upper edge of blotting paper. This is in line with axis of faller shaft. 2 = line of demarcation, or upper border of oil spray. The distance between lines 1 and 2 is 5 inches, and represents a clear zone. 3 = area of greatest density. This is 2 inches downward from line of demarcation.

EXPERIMENT 6.—This consisted of a series of successive one-minute experiments. In one minute, four complete movements of the carriage take place.

The bolster was oiled. I then held a piece of blotting paper against the faller shaft during the four draws, *i.e.*, for one minute. I replaced this by a second piece which I held for a further minute.

Result.—All the oil was distributed on the first paper as shown in Figure 9. No oil was found on the second blotting paper.

EXPERIMENT 7.—The purpose of this experiment was to determine what happens during each complete movement, or draw, occupying fifteen seconds.

The bolster was oiled. I now held a piece of blotting paper to the shaft and followed the carriage during its outward and inward movements. With the help of an assistant I placed a second piece of blotting paper to the same part of the shaft during the second draw, and also repeated this to test a third draw.

Result.—All the oil was sprayed upon the first blotter of the series, *i.e.*, in fifteen seconds.

EXPERIMENT 8.—Having oiled the bolster, with the aid of an assistant I held a piece of blotting paper to the faller shaft during the outward movement, changed it for a clean blotter during the two and one-half seconds, rest, and held this during the inward movement.

Result.—All the oil was found upon the first blotter, *i.e.*, sprayed off within nine seconds. The second blotter was clean and free from oil.

EXPERIMENT 9.—This experiment was made in order to determine at what point during the nine seconds all the oil is sprayed off.

With the aid of three assistants, one with a stop watch, the other two holding pieces of blotting paper ready, I had the machine oiled and held a sheet of paper to the faller shaft during the first three seconds of the outward movement. Assistant No. 1 immediately took my place with his blotter. He was followed by assistant No. 2. This experiment was repeated many times.

Result.—All the oil was sprayed off during the first three seconds after oiling.

Summary of Blotting Paper Test Results.—After oiling the bolster in the ordinary course of working, the total amount of oil thrown off upon a piece of blotting paper 12 inches long by $17\frac{1}{2}$ inches wide was found by chemical determinations to lie between 0.02 and 0.05 gm.

All the oil is sprayed off during the *first three seconds* of the movement of the carriage from the creel. The distribution of the spray in my three-second experiments was exactly similar to that found in all my earlier experiments, and formed a picture similar to that shown in Figure 9.

In three seconds the carriage has traveled 21 inches from the creel.

Experiment to Measure Throw of Oil.—As I desired to find the extreme throw, a dirty machine and dirty oil were again used for this experiment, as the dirt thrown off with the oil is easily observable. Two pieces of string were tied to the faller shaft 23 inches apart. A piece of blotting paper was held between the strings, the latter being kept taut and level with the shaft. By this means the distance between the blotting paper and the shaft was kept constant during any one experiment, and could be varied easily for successive trials. The bolster was oiled before each trial and the mule set going in the usual way.

The first distance tried, 30 inches, gave no result. By limiting and regulating the distance and repeating the experiments on different parts of the shaft, the greatest throw was found to be 27 inches from the bolster, or $20\frac{1}{2}$ inches from the shaft, when the blotting paper gave evidence of a few scattered specks of dirt about 11

inches below the level of the bolster—that is, below a man's knees.

Starting the Mule.—The starting lever, as will be seen from Figure 2, is placed midway between the two ends of the mule and just outside the radius of movement of the carriage. When the mule is at rest the belt, which transmits the power from the overhead shaft, is running on a free pulley. When the spinner pulls on his starting lever he is easing the belt from the free pulley to the fixed pulley on the shaft which drives the mule. His movement is not sudden but is a steady pull. His machine starts running as soon as the belt obtains a grip, which is practically at once. The spinner has to keep pulling the lever, however, until the belt is properly on the pulley.

The Spinner and the Oil Spray.—By means of a stop watch, and without his knowing that I was doing so, I timed a spinner who was about to start his machine. From the moment he commenced pulling his lever until he left to walk toward the carriage, he took six and one-half seconds. I timed a second man from the moment he started the mule until he touched that part of the faller shaft nearest to him; his time was seven seconds. I then asked a spinner to stop his mule with the carriage at the creel as usual, and informed him that I was going to time him in starting it. From the moment of commencing his pull on the lever until he touched that part of the faller shaft nearest to him he took five seconds.

I am definitely informed that a draw, or one complete movement of the mule, always takes place after starting up—that is, fifteen seconds elapse—before any spinner pieces a broken end, as by the time he gets to the carriage it is already too far from the creel, *i.e.*, 35 inches,[2] to allow of his reaching over to piece. He is, therefore, never in time to receive any of the oil spray, as this has all sprayed off in three seconds.

As a further check to this I pinned sheets of blotting paper over the overalls of a number of spinners, in such a way as to cover the lower part of the abdomen and the upper part of the thighs, and got them to oil their machines and start up in the usual way. Chemical test for oil on the blotting paper gave a negative result.

Combined Experiment.—The mule is stopped, the spinner seen in Figures 3 to 5 stands against the faller shaft, to which is attached a piece of blotting paper showing the oil and dirt distribution. The height of this man is 5 feet, 8 inches as he stands. From the point where the faller shaft touches his pubes to the lowest point of his left scrotum is $2\frac{1}{2}$ inches; that is to say, his scrotum lies entirely between the line of attachment of the blotting paper and the line of demarcation (that is, in the clear zone always found). It follows, therefore, that even if the spinner, after oiling the machine, was standing or bending over the faller shaft while another man started the mule, all the oil spray would be thrown upon his overalls at a level $2\frac{1}{2}$ inches below his scrotum, and the area of the greatest density would, therefore, be 2 inches downward toward his knees; that is, from $2\frac{1}{2}$ inches to 4 inches below his

[2] The carriage travels outward at the rate of 7 inches to one second.

scrotum. As explained in my previous experiments, however, such a position is never occupied. I have also demonstrated that, as the spinner leans over the faller shaft, his scrotum is $2\frac{1}{2}$ inches below, and $1\frac{3}{4}$ inches distant from the shaft.

Summary

1. The faller shaft exerts no pressure or friction on the scrotum because (*a*) the scrotum is below the level of the shaft; and (*b*) the spinner does not lean on the shaft in piecing.

2. Oil is not sprayed on to the faller shaft and, therefore, does not get to the spinner's overalls by this means.

3. The oil spray lasts only three seconds after each oiling. During this time the spinner is at the starting lever and his overalls receive none of the spray.

I submit, therefore, that oil and friction cannot be the cause of spinners' scrotal cancer.

Part 2. A Further Investigation of the Question of Oil

In view of the results of the researches made in the Cancer Experimental Laboratory (2) where it has been shown that medium mineral oils will cause cancer, before exonerating oil from all blame in this particular case or even giving it the benefit of the doubt, it is necessary to proceed to a more intimate investigation. The oil used is a medium oil with a specific gravity of 0.9007.

A fact which strikes one on entering the spinning room in a mill is that the floor is wet with oil; in fact, in old mills oil actually drips through to the floor below. Owing to faults in the machinery the spinner often has to kneel on the floor to carry out minor repairs. His overalls thus absorb oil from the floor, at the knees. His hands also become oily, and when the repairs are completed he invariably rubs them dry upon the flanks of his overalls and afterward finishes the cleansing process with a piece of dry waste.

Four oil areas are thus found upon the overalls, especially at the end of a week's work: *viz.*, one over each knee, one on each thigh, particularly in front of the great trochanters, round the overalls to the middle of the legs and groin in front. A parade of a number of spinners on a Saturday morning in the overalls which they had been wearing since the previous Monday confirmed this. There was no visible oil and dirt area in the scrotal region; the most marked areas were over the knees.

As a further test, arrangements were made with three spinners to start work on a Monday morning with clean overalls lined around the scrotum, groin, lower abdomen, and down the legs to the knees with a piece of absorbent cotton cloth. Two wore blue overalls, and one wore white. These men worked a full week in the usual way and on Saturday morning at 12 noon I received the overalls and linings for examination. On the outside of the scrotal region the overalls felt slightly damp to the touch, but on the inside they were dry, as was also the soft cotton lining in this region. One suit of overalls selected for this test was well worn and frayed around the fork, and even had a small hole in this area about the size of a shilling, through which the white lining could be seen.

Two linings and one pair of overalls with lining were taken by me, and delivered direct to Mr. G. W. F. Holroyd, M. A., F. I. C., Head of the Chemical Department, Blackburn Technical College. The overalls and linings were carefully examined by the naked eye and with lenses. The overalls showed the well-marked four oil areas as described, but the area against which the scrotum could possibly play appeared free from oil. Traveling, however, from the oil areas mentioned toward the scrotal area, the cloth suggested an amount of oil capillary movement. As it was unnecessary to make any determinations regarding the overalls as a whole, we confined ourselves to the scrotal area.

For this purpose a central piece was cut out, measuring 6 inches across, and 7 inches down the legs, thereby including all that portion of the overall which could possibly touch any part of the scrotum. The outer edges of this piece involved a fringe of each oil area, more particularly the flanks. The weight of this piece of cloth was 7 gm. (The weight of a new piece of the same material measuring 12 inches by 12 inches is 22 gm.) The amount of mineral oil extracted was 0.9008 gm.; the amount of fatty oil (this represented scrotal secretion) was 0.11 gm.

The absorbent linings measured 15 inches by 15 inches, and each weighed 20 gm. The linings from the blue overalls gave the following determinations: mineral oil, 0.2162 gm.; fatty oil, 0.2162 gm. The lining from the white overall gave: mineral oil, 0.1632 gm.; fatty oil, 0.1632 gm.

From these very definite facts I suggest that 0.2 gm. of any mineral oil found upon a piece of cloth 15 inches by 15 inches at the end of one week's work cannot have any influence upon the production of an epithelioma.

The naked eye examinations of these linings showed that any suspicion of oil was limited to the outer edges; centrally, and where the scrotum played, the linings were faintly stained yellow, and this we take to represent the fatty oil secreted from the scrotum.

Reviewing these several facts, I am of the opinion that all the oil is received upon the overalls first from the floor, and second from the hands of the spinner, which in turn receive the oil from the floor. This is a daily increasing quantity, commencing in four limited areas and from these spread by capillary attraction in all directions. This spread, however, does not reach the very limited area of the overall which plays upon the very definite sites occupied by spinners' epithelioma of the scrotum.

The spinner works in his bare feet on the oily floor, his feet are oily, and his socks are definitely oily. I have found no spinner who washes his feet oftener than once in two weeks. From the time he leaves his work until he returns he has the friction of his socks and boots or clogs upon his oily feet, yet he never suffers from cancer of the feet or even from sores. The skin of his feet is soft and healthy. Spills of wood from the floor get into the soles of the feet; they are removed and the wounds—painted with iodine—rarely even suppurate.

Capillary Experiment.—As stated, 0.9 gm. of oil was extracted from that piece of overall cut out at the end of

one week's work of five and one-half days. This oil was found around the outer edges. It is further noted that only slightly more than 0.2 gm. of oil penetrated through the overalls to the piece of absorbent cotton 15 inches square, also worn for the said five and one-half days; and this oil, too, was confined to the four corners which came in direct contact with the four receiving oil areas.

I now desired to study the capillary movement of this oil. For this purpose I took two pieces of overall cloth, each measuring 6 inches by 7 inches, one piece new, one piece washed and dried. Eight corks were fastened to a board, upon which these two pieces of cloth were fixed. Four edges were marked off, to represent the areas of contact with the overall working conditions as previously described. Then 0.9 gm. of machine oil as used at the mills was placed in a burette, and its drop value estimated. From the burette used this equaled 43 burette drops.

A five and one-half days' experiment was now carried out so as to represent as nearly as possible working conditions. The two upper outer edges represented the oil areas on the thighs; the lower edge represented oil on the knees. The oil was added as follows:

	Number of Drops[1]		
	On Thighs		*On Knees*
Day			
1st	3	3	4
2nd	4	4	3
3rd	3	3	4
4th	4	4	4
	14	14	15

[1] Total, 43 drops, or 0.9 gm.

At the end of five and one-half days the capillary movement on new cloth was 4.25 cm.; that on washed cloth was 3 cm. The area of cloth which would act upon the scrotum, and particularly upon the sites of this disease, remained free from any oil.

These experiments were carried out at the Darwen Secondary and Technical Schools, were observed by, and all measurements were carefully checked by, J. Foulds, A.R.C.S., F.I.C., and A. Holderness, M.Sc.

Taking all the facts, it can be definitely stated that no oil reaches the scrotum, and therefore oil cannot be a factor in the causation of spinners' scrotal epithelioma.

Part 3. History

The two usual sites of spinners' cancer are very definite and limited. They are situated upon (*a*) the inner lower medial side of the left half of the scrotum, and (*b*) the medial lower edge of the right half, as shown in Figure 10. This very limited area as a site of disease, especially arising upon a skin surface which is generally equally susceptible, forces the conclusion that some very specific operating factor or factors must be at play. Such factors must be peculiar to the spinner, his clothing, and his movements.

Examination of the spinner shows that he is not particularly clean as to his person. I have examined several hundred spinners and have in all cases found the scrotum sticky and dirty. Working in a hot and—contrary to the usual conception (5, p. 35)—somewhat dry atmosphere and drinking on the average 1 pint

of water an hour, he perspires freely. His overalls, being thin, absorb little

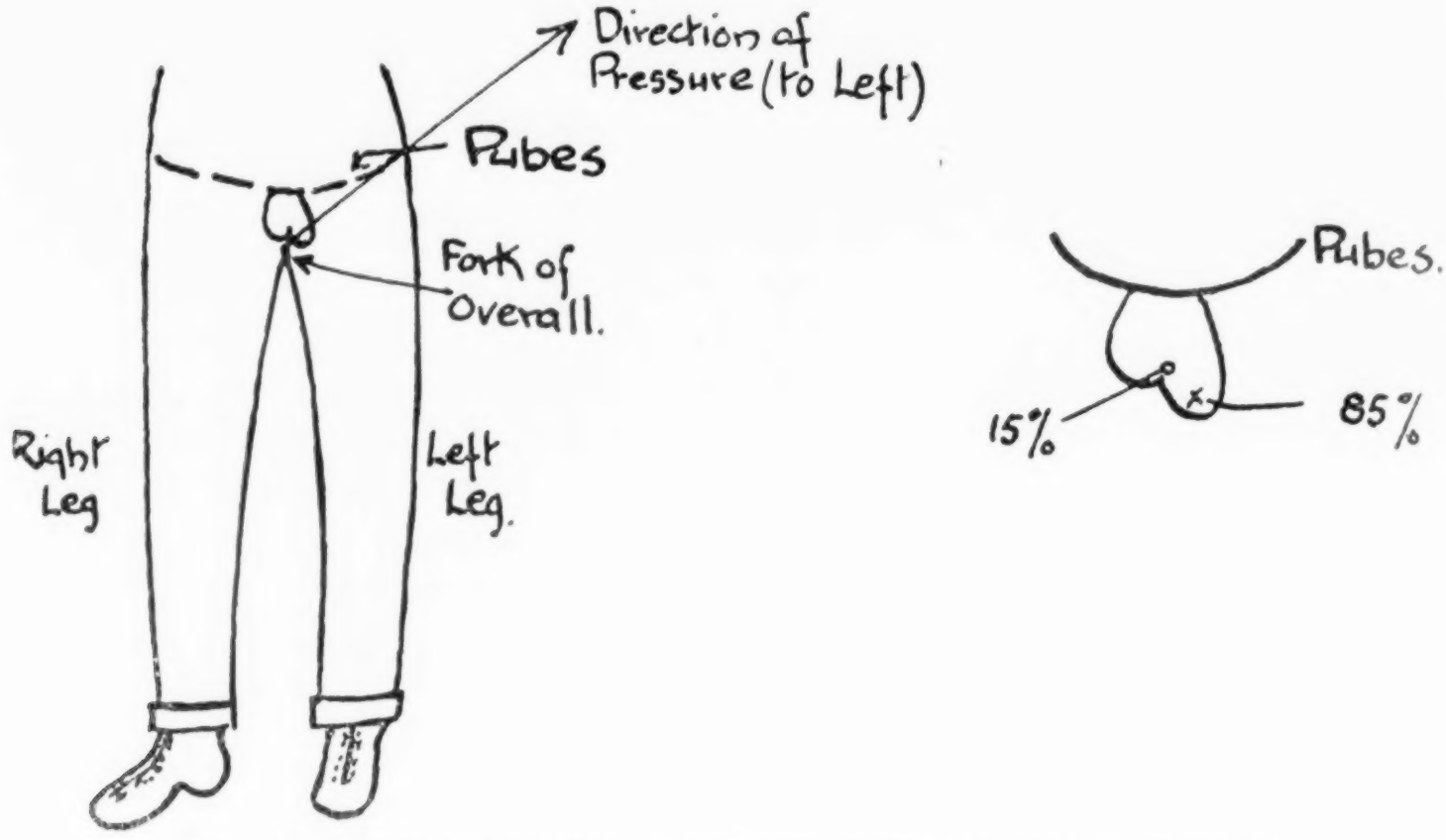

FIG. 10.—Showing location of pressure caused by fork of overalls.

of this. Evaporation results in a concentration of dirt and salts on the skin. The scrotum, a dependent organ, whose corrugated skin lends itself particularly to the retention of dirt, possibly receives more than its share through gravitation.

There is no reason to suppose that the spinner of today is any dirtier than his forbears. While the dirty scrotum, the mineral oil, and the same movements required of the man have existed since 1880, scrotal cancer has only lately become serious as the statistics shown in Table 1 disclose. It would seem, therefore, that it is necessary to find some recent factor or factors operating on the scrotum, and on a definite part of it.

A few cases of spinners' scrotal cancer can be traced back to 1900, but it was not until after the war that attention was directed to this disease because of its rapid increase. In 1922 the Home Office made it notifiable under the Factory Act. The information regarding spinners' scrotal cancer given in Table 2 was supplied to me by the Factory Department, Home Office.

Overalls

From 1880 until about 1905, spinners wore white overalls. The cloth of which these overalls were made, called "fustian," was of a soft, kindly nature, and contained no chemicals. Blue overalls began to make their appearance about 1905, the cloth being a hard, cheap material containing from 25 per cent. to 40 per cent. of size (magnesium chloride, zinc chloride, and sago). Another kind of white cloth also began to be worn at this time, differing from the blue only in the absence of coloring matter.

The older men, accustomed to the soft white fustian, continued to wear overall is the history of the increase in the number of spinners suffering

TABLE 1.—STATISTICS ON INCIDENCE OF SPINNERS' SCROTAL CANCER, 1900 TO 1925

BLACKBURN ROYAL INFIRMARY				BOLTON INFIRMARY[1]		MANCHESTER ROYAL INFIRMARY		CASES COLLECTED BY ASSOCIATION OF OPERATIVE SPINNERS[2]			
Year	No.	Year	No.	Year	No.	Year	No.	Year	No.	No. Died Since Onset	No. Died Each Year
1900	0	1913	1								
1901	1	1914	1								
1902	1	1915	2	No early records		1902					
1903	1	1916	1			to	69[3]				
1904	1	1917	4			1921		1917	12	8	2
1905	1	1918	0					1918	17	9	7
1906	1	1919	5					1919	9	3	5
1907	1	1920	3	1920	1			1920	11	6	6
1908	1	1921	5	1921	4			1921	16	9	2
1909	1	1922	3	1922	8	1922	5[1]	1922	25	10	8
1910	4	1923	6	1923	6	1923	6[1]	1923	26	11	14
1911	4	1924	2	1924	10	1924	5[1]	1924	57	13	21
1912	2	....	.	1925 (to Sept.)	5	.....	...	1925 (to March)	..	..	4
Totals.....			52		34		85		173	69	69

[1] All left sites.
[2] Average age at onset 52 years; average age at death 53 years.
[3] Of this number, 84 per cent. were left sites; 16 per cent., right or central.

it, the younger men wearing the cheaper material. Thus the blue overalls began gradually to displace the others until 1914, when some 90 per cent. of spinners were wearing blue, the remainder wearing the cheap white. The soft fustian overall is now practically unknown.

Oil, dirt, and all movements performed by the spinner, being constant factors throughout the history of the trade, it is necessary to find other factors to explain the increase in the incidence of this disease. I suggest that the history of the present type of from this disease. The statistics given in conjunction with what is known of the time required for the development of the disease bear out this suggestion (2) (3) (4).

The spinner has two pairs of overalls in use at a time, the pair he is wearing and a pair at the wash. Every Saturday he takes home to be washed the dirty pair which he has been wearing all week, and every Monday morning he appears with a clean pair. One pair is generally fairly new and the other fairly old, and the men, on examination, are found to be stained

around the scrotum and down the legs with blue dye (2, p. 28) (8). A pair of overalls generally lasts about eighteen weeks.

TABLE 2.—NUMBER OF CASES OF SPINNERS' SCROTAL CANCER AND NUMBER OF DEATHS FROM THIS CAUSE NOTIFIED TO THE HOME OFFICE, 1923 TO 1925[1]

YEAR	NUMBER OF CASES NOTIFIED	NUMBER OF DEATHS
1923	14	1
1924	57	13
1925	54	28
Totals.....	125	42

[1] The total number of mule spinners was 23,000.

The overalls are worn next the skin. They are held up by means of cloth straps of the same material, sewed on at the back and coming over the shoulders to button in front. In the piecing movement, the stretching out of the left arm and the consequent raising of the left shoulder pull on the loosely worn overalls and cause slight pressure and friction on the very points of the scrotum on which the epithelioma is usually found.

Detailed study of a spinner's movements while piecing is very interesting. The right testicle is situated at a higher level than the left, and while spinners are usually dressed to the left in their overalls, as men commonly are, the fork of the overalls is in such a position that, when the spinner reaches over the faller shaft, the right testicle immediately passes slightly upward and backward, and the left testicle remains in its lower position. The fork of the overalls passes between the testicles, thereby causing pressure upon the scrotum in a direction obliquely upward and outward to the left. (See Fig. 10.) It will also be seen that the inner side of the overall leg presses against the medial side of the left scrotal pouch containing the left testicle; this is the usual stituation of the epithelioma. These rapid intermittent frictions, some 240 an hour, acting upon a dirty scrotum plus the aniline dye is, I suggest, the cause of this disease (9) (10).

In a large number of mills women have always been employed at mule spinning, and during the war their number was much increased. They wear a blue cotton skirt with an underpetticoat only. They have the same duties to perform as a male mule spinner, yet I can find no case of labial cancer recorded. Among worsted spinners, who use a mule similar to that used in cotton spinning, the oiling of the bolster is carried out in a similar way, and the oil used is a mineral oil with a specific gravity of 0.9007, the same oil as is used in cotton spinning. The wool spinner leans over the faller shaft to piece his ends, just as does the cotton spinner. I can find no case of wool spinners' scrotal cancer, except one case reported to the Home Office in 1924. I further inquired at a large firm of wool spinners, Messrs. Paton and Baldwin, and am definitely informed that they know of no case arising among their spinners, and they have been in business for over sixty years. Wool spinners, however, wear their overalls over an undergarment, and this is, in my opinion, a vital factor.

The Fine Cotton Spinners' Association, Manchester, has made specific inquiries, at my request, in regard to the conditions obtaining in France. I submitted a list of questions and, in reply thereto, I am definitely informed from Lille, France, that: (1) No cases of epithelioma of the scrotum are known among the French spinners. (2) The spinning mules and working conditions are similar to those obtaining in Lancashire. (3) The spinners wear blue, white, or black overalls of the same material as that worn in Lancashire, upon their bare legs, and they work in bare feet. (4) They are subject to the same oil conditions as is the case in Lancashire. (5) They do *not* wear shoulder straps; their overalls are supported by a waist belt.

These factors further support my argument and experimental proofs, that this disease is not due to conditions within the mill, but is due to the friction (plus the scrotal state) resulting from the shoulder pull upon an inelastic brace, causing the overall fork to operate upon the scrotum as already described. In France the waist belt supports the overalls, so that when the spinner leans over the faller shaft in order to piece the cotton, the shoulder being free, there is no pull upon the overalls and, therefore, no friction of the overalls upon the scrotum at any point. The wool spinner, as I have already stated, has the protection of a soft undergarment.

During my investigations, I have seen twenty-nine spinners who have been operated upon for this disease; twenty-eight wore blue overalls, one wore white. All had the disease at the usual site on the left side of the scrotum.

All the figures given are very definite proof that this disease is rapidly increasing among male mule spinners, and I am now, after my experimental work, strongly of the opinion that the spinner should wear the white fustian overalls supported by an elastic brace; or, if he wears the blue or the hard white overalls, he should have next his skin some short undergarment of soft material, and should wear an elastic brace or a waist belt. Cleanliness of the scrotum is also required of him. If these measures were adopted, I feel sure that this disease would seldom be seen. Further, I suggest, as I have definitely proved that all the oil found upon the overalls is received from the floor, that the spinning room floor should be washed at least every two years, in order to prevent any accumulation of oil.

Note.—One of the twenty-nine spinners whom I examined had in my opinion an early recurrence of the disease. A small white scaly patch was observable situated near the midline anteriorly and at the most dependent part of the right side of the scrotum, just in line with and near to the scar of his previous operation. This patch was hard to the touch and in its center was seen the opening of a skin gland. I picked off this scale and found a raw-looking surface which easily bled.

The man informed me that, because of the itching and tingling sensations from which he suffered at the commencement of his previous epithelioma, he also picked off the scale, after which, on several occasions, a little blood came away. All the pa-

tients that I saw experienced these sensations.

Conclusions

Spinners' scrotal epithelioma is not caused by oil spray thrown by the working mule, neither does the faller shaft take any part in its causation.

The oil found upon the spinner's overalls is absorbed entirely from the spinning room floor, and gradually spreads by capillarity from the four receiving areas, but does not reach by the end of five and one-half days the circumscribed area of the overalls which operates upon the scrotum at the definite site of this disease as found among spinners.

The definite etiologic factors are, in my opinion, (1) the dirty scrotum; (2) the added factor of the dye; and (3) the friction from the hard, rough, and unkindly cloth, especially at the fork of the overalls which contains the roughly made seam, acting very definitely upon the exact scrotal situation where this disease is always found; this friction being aggravated by (4) the use of an inelastic brace.[3]

[3] So far as I have been able to discover, cancer of the scrotum is relatively rare in the United States. Cases have been reported among men working with tar and with the paraffin oils, but these cases are few and not well defined.

There seem to be very few recorded cases of cancer which are directly traceable to the cotton trades, such as spinners' scrotal cancer. This fact may be due to:

1. Lack of observation heretofore.
2. The tendency of mill hands in the South to wear trousers with belts rather than shoulder strap overalls.
3. The general tendency of mill hands in the North, the majority of whom wear overalls, to wear also some sort of underclothing.

Any one of these factors would undoubtedly tend to reduce the occurrence of anything like the spinners' cancer as discussed in Dr. Robertson's article.

In Massachusetts at the present time an intensive study of cancer is being conducted by the state authorities, with special reference to its etiology. This investigation should call attention to any types of cancer which may be of industrial origin. As yet, however, no definite conclusions have been reached.—*Derric C. Parmenter.*

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A STUDY OF THE LEAD LINE, ARTERIOSCLEROSIS, AND HYPERTENSION IN 381 LEAD WORKERS*

MAY R. MAYERS, M.A., M.D.

Bureau of Industrial Hygiene, New York State Department of Labor

THE investigation recently completed by the Bureau of Industrial Hygiene of the lead industries in the state of New York and of the health of 381 lead workers has thrown rather interesting light on a number of phases of lead poisoning. Most important of these, perhaps, were the blood findings already reported in THIS JOURNAL in May, 1926, in an article on "Lead Anemia." Of the other findings those relating to the lead line, arteriosclerosis, and hypertension are thought to be of sufficient interest to warrant a special report.

Physical examinations were made in twenty-three plants in fifteen leading industries in the state of New York. The workers were exposed to lead in the following forms: lead fumes, red lead paste, red lead and litharge dusts, dry and wet paints, dry and wet chrome colors, dry and wet pottery glaze, pig lead and metallic lead dust, and white lead as such. All examinations were made in the plants so that the series includes no cases of incapacity due to acute lead poisoning.

STANDARDIZATION OF TERMINOLOGY

One of the questions which presented itself at an early stage in the investigation, and one which grew increasingly difficult to answer as time went on, was: Exactly what *is* lead poisoning? Before entering upon the discussion at hand, therefore, it might be well to stop for a moment and consider this question. If one consults the voluminous literature on the subject, one is immediately struck with the fact that authorities have apparently disagreed for generations as to precisely what should constitute a diagnosis of lead poisoning. There appear to be those on the one hand who will not make a diagnosis of lead poisoning unless acute lead colic is present; while there are others who take the position that the presence of stippled cells in the blood in itself constitutes a sufficient basis for a positive diagnosis, even in the absence of all clinical manifestations of this disease. A large number of intermediate positions have been taken by as many different medical men.

From the standpoint of the physicians who are constantly being called upon to make a positive diagnosis of lead poisoning, as well as from the standpoint of those charged with the administration of the compensation law, this lack of standardization of diagnosis is most unfortunate as it gives rise to considerable needless confusion. It was partly this situation which

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prompted the United States Public Health Service in connection with its study of the pottery industry to attempt a classification of signs, symptoms, and laboratory findings, in which each was more or less arbitrarily assigned a definite relative weight. The Bureau of Industrial Hygiene, because it welcomed any effort at standardization, attempted to use this proposed classification in the present study, but unfortunately without any great degree of success. It is always extremely difficult to make the diagnosis of any disease dependent on a system of weights and measures, no matter how carefully they have been figured out; and so it proved in this instance.

Many of the differences of opinion as to diagnosis are, on analysis, found to be due to differences of opinion as to the definition of the term "poisoning" rather than to any fundamental differences in the medical interpretation of cases. Poisoning appears to be a rather unfortunate term, moreover, in that it tends to convey—particularly to the lay mind—ideas of extreme distress and dramatic episodes. It is, in reality, a peculiarly inapt term to apply to a disease which is so inherently insidious and cumulative in character, and in which very acute symptoms are (at the present time, at any rate) relatively infrequent. It is felt, therefore, that considerable progress might be made in the direction of clarifying the situation and standardizing the diagnosis, if the term "lead poisoning" were arbitrarily reserved entirely for cases presenting toxic episodes such as acute lead colic, lead palsy, or encephalopathy, and if the broader and more general term "lead absorption" were used to cover all cases where there is any laboratory or other positive evidence that lead has been absorbed into the body, whether or not this is accompanied by clinical manifestations of the disease. Used in this sense, all cases of lead poisoning are merely special cases of lead absorption which present evidences of acute intoxication. The term lead absorption has unfortunately been used rather loosely in the past, by some, to refer to cases which they vaguely regarded as "mild" cases of lead poisoning. There has been very proper objection to its use in this way. Lead absorption used in the sense above suggested would, by definition, not readily lend itself to varying interpretations; indeed, it is an expressive term because it definitely refers to the etiologic factor itself rather than to its protean symptomatic manifestations.

For purposes of clarity in the present discussion, at any rate, I shall take the liberty of speaking in terms of lead absorption rather than of lead poisoning. Indeed, since all of the men examined were at work, the present series contains no cases of severe intoxication, and therefore no cases of lead poisoning in the limited sense in which I am for the present arbitrarily using this term.

Lead Line in the Gums

The foregoing discussion of terminology has a direct bearing on the question of the diagnostic significance of any such physical sign as the lead line in the gums. That the presence of this single and well-defined sign (when it *is* well defined) is direct evidence of lead absorption is generally accepted—lead

was absorbed and subsequently deposited in the gums. The practical questions which must be borne in mind, however, by the examining physician are: (1) May active lead absorption occur in the absence of this physical sign? (2) May the lead line in the gums persist long after active lead absorption has ceased? (3) To what extent should the presence or absence of the lead line in a lead worker affect the interpretation of the symptom-complex which the patient presents at the time he is examined—as, for example, a stomach ache? It is a common experience that stomach ache in a lead worker is only too frequently diagnosed as lead colic, without further investigation. When a lead worker with a lead line in his gums, however, comes to a physician and complains of stomach ache, the diagnosis is almost a foregone conclusion. And yet a lead worker either with or without a lead line in his gums may have a stomach ache for any of the reasons that anyone else may.

An analysis of some of the data on the lead line obtained in the present study brings out the pertinence of these considerations. There were, in all, among the 381 workers examined, thirty-one cases of lead line in the gums, or 8.1 per cent. No attempt will be made at this time to discuss the difficulties in differentiating a true lead line in the presence of cyanotic gums and carious teeth, both of which are so common among lead workers. The thirty-one cases here discussed were sufficiently definite to leave no doubt as to the diagnosis. Of this number, ten gave no other evidence of lead absorption. Examination of their blood showed no evidence of lead anemia, and their urine was negative for lead, showing that there was apparently no active lead absorption going on at the time they were examined. It would seem proper to infer, therefore, that in the case of these ten men, at least, the lead line had in all probability been deposited at some previous time when active lead absorption had taken place, and that these lead deposits had remained there, inert, until the present time. Teleky has reported a lead line in the gums of a worker eleven months after exposure to lead had ceased. In the present investigation, approximately one-third of the men with a definite lead line in their gums appeared to be in the position of this man. For them, the presence of the lead line would not necessarily be contributory evidence in favor of a diagnosis of lead colic in the absence of other findings. On the other hand, in the present series there were 201 men who showed laboratory evidences of active lead absorption but who nevertheless did not have a lead line in their gums. Evidently the lead line may frequently be absent, even when active lead absorption is taking place.

The practical importance of differentiating workers who are actively absorbing lead at the time the lead line is observed from those who merely have inert deposits of lead in their gums from some previous time cannot be overemphasized. In order properly to appraise the diagnostic significance of the lead line in any particular case, repeated laboratory analyses should be made both of blood and of urine for evidences of active lead absorption. It is the presence or absence of active lead absorption, and not the presence

or absence of the lead line, which is essential to a proper interpretation of the symptom-complex presented by a given patient.

It must be remembered, however, that every worker who has any lead stored in his body—whether in his gums, in his bones, or elsewhere—is at all times a potential case of acute lead poisoning. The onset of an intercurrent infection or some change in his metabolism may at any time cause a sudden mobilization of this stored lead, with the result that it is thrown into his circulation in toxic amounts, and an acute attack of lead poisoning may ensue. Such workers not only require watching by the industrial physician, but they require proper prophylactic treatment directed toward a slow mobilization with a gradual elimination of these lead deposits from their bodies.

Arteriosclerosis

The belief that long-continued exposure to lead produces pathologic changes in the arterial walls which predispose to an early arteriosclerosis made the study of this condition among the large group of lead workers examined a very interesting one. The total number of cases of arteriosclerosis was found to be eighty-six, or 22.5 per cent. of the 381 workers examined. All of these cases, however, occurred in men over 30 years of age, so that the actual percentage of arteriosclerosis based on the 227 men in this age group is, in reality, 37.8 per cent. Superficially, this would appear to be a rather high percentage.

In evaluating these figures, however, it was recognized at the outset that due allowance must be made for other factors, principally those of age and duration of exposure, since it requires a long time for arterial changes to take place. That chronic alcoholism plays an important part in the production of arteriosclerosis is well known, and

TABLE 1.—INCIDENCE OF ARTERIOSCLEROSIS IN 381 LEAD WORKERS CLASSIFIED BY AGE GROUPS

AGE GROUP *yrs.*	TOTAL IN GROUP	CASES OF ARTERIOSCLEROSIS	
		Number	Per Cent.
Under 16	1	0	0
16–18	16	0	0
19–21	29	0	0
22–30	108	0	0
31–40	116	20	17.2
41–50	66	34	51.5
51–60	27	18	66.6
Over 60	18	14	77.7
Total.....	381	86	22.5

TABLE 2.—INCIDENCE OF ARTERIOSCLEROSIS IN 381 LEAD WORKERS CLASSIFIED ACCORDING TO DURATION OF EXPOSURE

DURATION OF EXPOSURE	TOTAL IN GROUP	CASES OF ARTERIOSCLEROSIS	
		Number	Per Cent.
Under 2 mos.	28	3	10.7
2–6 "	57	5	8.7
7–11 "	21	3	14.2
1–2 yrs.	72	17	23.6
3–5 "	86	20	23.2
6–10 "	36	5	13.8
11–15 "	28	9	32.1
16–20 "	19	7	36.8
21–30 "	25	11	44.0
Over 30 "	9	6	66.6
Total.....	381	86	22.5

it is to be regretted that this factor could not be entirely eliminated. Since almost all of the workers examined drank more or less, this was manifestly impossible. Those who were known to drink in great excess, however, were excluded from the series. Tables 1 and 2 show the incidence of arteriosclerosis among the 381 lead workers distributed by age groups and according to duration of exposure.

Bearing in mind that alcoholism must be reckoned with in the interpretation of results, the cases were then further distributed so as to bring out more definitely the correlations between age and duration of exposure to lead. Since arteriosclerosis develops very slowly, the workers were arbitrarily divided into three groups. The first group was limited to those who had been exposed to lead for two years or less. Arteriosclerosis found in this group could hardly be regarded as bearing any relation to lead since the duration of exposure was too short. This group could, therefore, be considered more or less in the light of a control series. Those who had been exposed to lead for five years or more were selected for group 2, and those exposed for over ten years were put into group 3. (See Table 3.) Within these groups, the workers were then classified by age, omitting all workers under 31 years of age, as no cases of arteriosclerosis were found among them.

Of those exposed to lead two years or less, it will be observed that, in the successive age groups, the percentages of cases showing arteriosclerosis were 15.2, 56.5, 71.4, and 75, respectively. This is the control group. The corresponding percentages for the group which was exposed for over five years were 23.5, 31, 66.6, and 78.5, respectively; and for the last group, those exposed for over ten years, 20.8, 40.9, 64.2, and 76.9. Figure 1 presents graphically these correlations between age and duration of exposure.

TABLE 3.—INCIDENCE OF ARTERIOSCLEROSIS IN 172 LEAD WORKERS CLASSIFIED BY AGE GROUPS AND DURATION OF EXPOSURE

AGE GROUP *yrs.*	TOTAL IN GROUP	CASES OF ARTERIOSCLEROSIS	
		Number	Per Cent.
Exposure for Two Years or Less (Control Group)			
31–40	46	7	15.2
41–50	23	13	56.5
51–60	7	5	71.4
Over 60	4	3	75.0
Total.....	80	28	35.0
Exposure for over Five Years			
31–40	34	8	23.5
41–50	29	9	31.0
51–60	15	10	66.6
Over 60	14	11	78.5
Total.....	92	38	41.3
Exposure for over Ten Years			
31–40	24	5	20.8
41–50	22	9	40.9
51–60	14	9	64.2
Over 60	13	10	76.9
Total.....	73	33	45.2

Considering the age group from 31 to 40 years, it will be seen that the incidence of arteriosclerosis in the control group (*i.e.*, those exposed for two years or less) is lower than for

those exposed for longer periods of time. It will be observed, however, that the incidence of arteriosclerosis was found to be higher among those exposed to lead for over five years than among those exposed for over ten years. In the two successive age groups from 41 to 50 years and from 51 to 60 years, the incidence of arteriosclerosis appears to be highest among the controls.

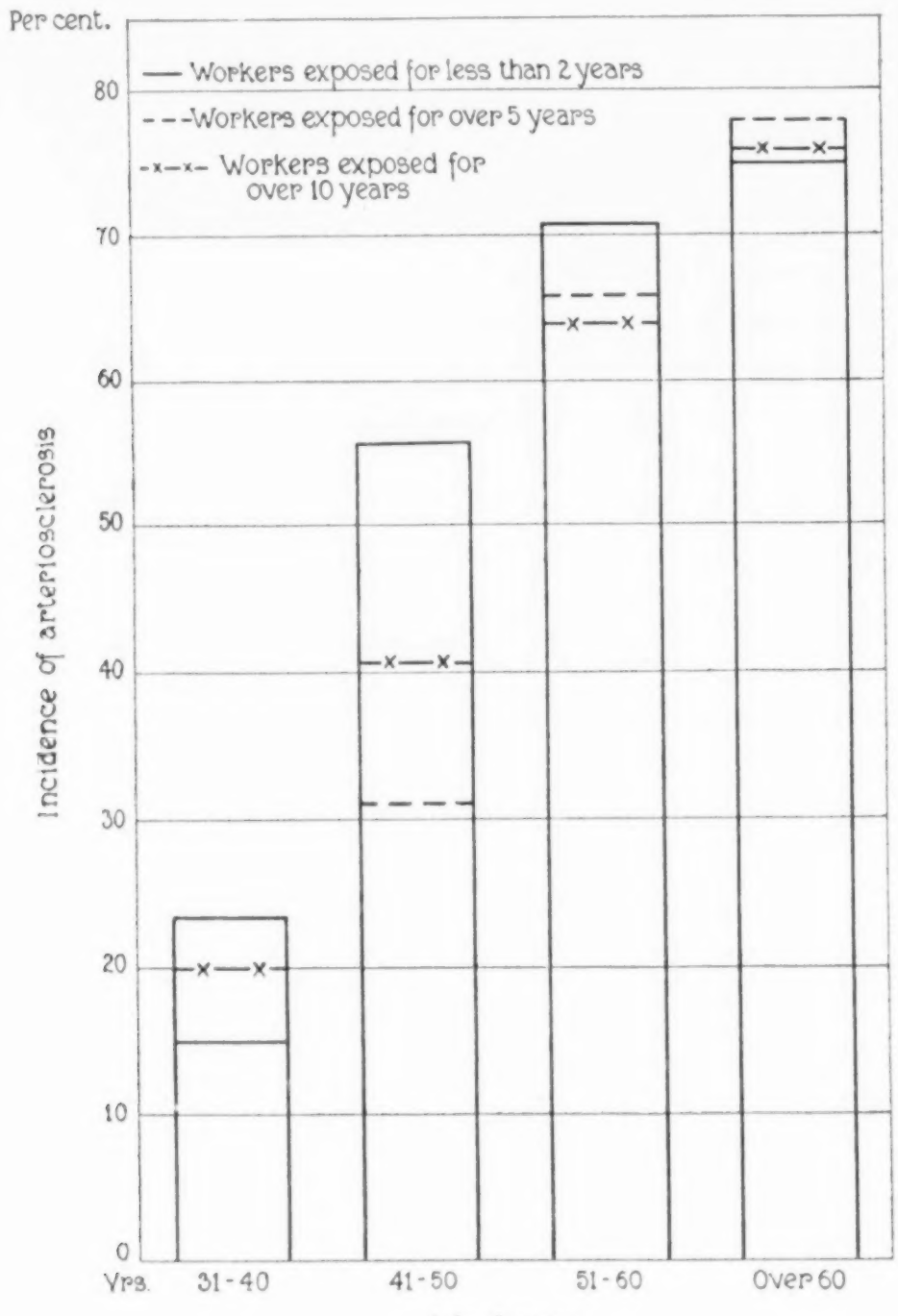

FIG. 1.—Incidence of arteriosclerosis in 172 lead workers classified by age groups and duration of exposure.

It will be seen too that, generally speaking, the incidence of arteriosclerosis increases with each age group, as would normally be expected. Examining the third age group (51 to 60 years), however, it will be seen that the percentage of arteriosclerosis among the workers exposed for two years or less, for over five years, and for over ten years, respectively, tends to be more nearly the same than in the preceding age group. In this group, age is apparently beginning to outweigh all other factors in the etiology of arteriosclerosis. Here again, curiously

enough, the incidence of arteriosclerosis is highest among those exposed to lead so short a time that lead is not regarded as a probable cause.

In the last group, workers over 60 years, the incidence of arteriosclerosis is almost the same regardless of duration of exposure to lead. Here apparently age asserts itself as the dominant etiologic factor.

The group from 31 to 40 years of age was regarded as of especial significance, since it was felt that here both age and chronic alcoholism tended to be reduced to a minimum as complicating etiologic factors in the production of arteriosclerosis. These cases were therefore still further analyzed with reference to exposure to lead for increasing periods of time. (See Table 4.)

There appears to be rather a high incidence of arteriosclerosis in this age group—17.2 per cent. Furthermore, the incidence of arteriosclerosis appears to increase steadily with increased exposure to lead until one reaches the group which has been exposed for over fifteen years, when there is a marked drop. Of the 13 men who had been exposed for over fifteen years, only 1 (7.6 per cent.) showed arteriosclerosis. There are undoubtedly great differences in personal susceptibility. When for purposes of comparison one considers the 82 men in this age group who had been exposed for five years or less—*i.e.*, those at

TABLE 4.—INCIDENCE OF ARTERIOSCLEROSIS IN LEAD WORKERS FROM 31 TO 40 YEARS OF AGE WHO HAD BEEN EXPOSED TO LEAD FOR INCREASING PERIODS OF TIME

DURATION OF EXPOSURE *yrs.*	TOTAL IN GROUP	CASES OF ARTERIOSCLEROSIS	
		Number	Per Cent.
2 or less	46	7	15.2
3–5	36	5	13.8
6–10	10	3	30.0
11–15	11	4	36.3
16–20	11	1	9.0
21–30	2	0	0
Over 30	0	0	0
Total.....	116	20	17.2

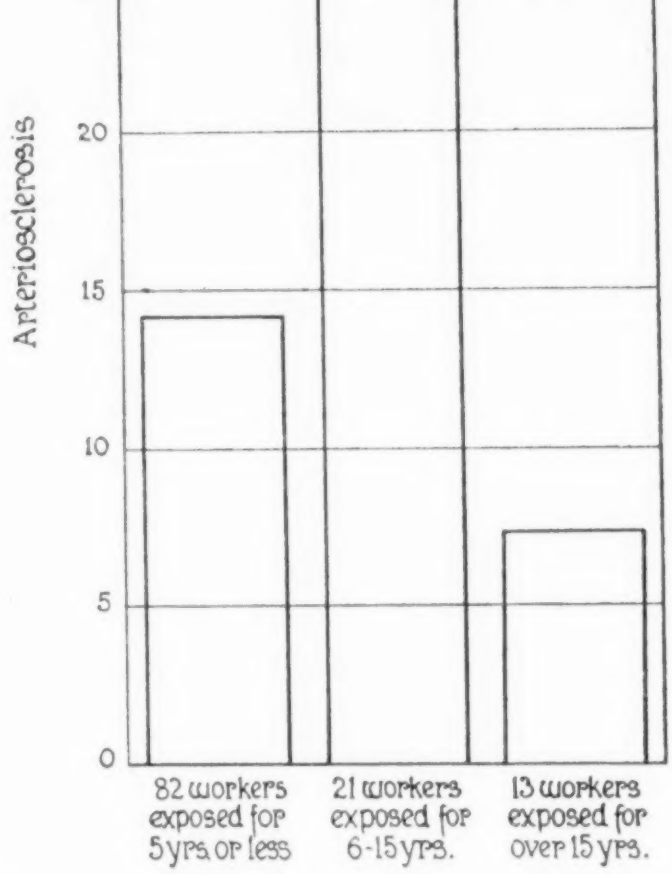

FIG. 2.—Relative incidence of arteriosclerosis in lead workers from 31 to 40 years of age, exposed to lead for increasing periods of time.

the other extreme—one is rather struck with the fact that 12, or 14.6 per cent., were found to have arteriosclerosis; or, going still further back, to the control group or those 46 men who had been exposed to lead for two years or less, the incidence of arteriosclerosis is as high as 15.2 per cent. However, in the 21 men exposed to lead from six to fifteen years the incidence as shown in the table is 33.3 per cent.—considerably above the average for the group as a whole. Why this is so is not entirely clear. Figure 2 presents these relationships graphically.

It is to be regretted that the number of men examined who fell into this age group (31 to 40 years) was not many times greater. From the material at hand, however, one is impressed with the high incidence of arteriosclerosis among *all* of the men in the social and economic classes from which lead workers are recruited, rather than with any close relationship between this high incidence and prolonged exposure to lead. Such a relationship may exist, of course, and possibly a study of a much larger series of lead workers would bring it out. The present study of 381 lead workers, however, does not demonstrate this relationship very convincingly.

It is of interest in this connection that the present findings appear to be in accord with those of Dr. S. A. Smith, who, in connection with an investigation of lead poisoning at Broken Hill in 1920, found that the incidence of arteriosclerosis among lead workers was high, but that it was no higher than among a corresponding group of sandstone miners whom he investigated for purposes of comparison.

Hypertension

In studying the relationship between hypertension and exposure to lead, it was recognized that there was some difference of opinion among authorities as to whether or not such a relationship exists. The United States Public Health Service, in a study of the pottery industry, found a somewhat high incidence of high blood pressure among their cases. Similar findings have been reported by Legge and by Oliver. The recent investigation of lead poisoning by the Harvard School of Public Health did not seem to bear out this point. The present series has been analyzed with considerable interest, therefore, from the standpoint of the incidence of high blood pressure. Theoretically, in view of the doubt already expressed as to the relationship of arteriosclerosis to prolonged exposure to lead, there would seem to be reason to doubt also the secondary relationship of a hypertension based *solely* on an arteriosclerosis of this etiology.

In making the diagnosis of hypertension in these cases, the standards used by the Metropolitan Life Insurance Company were taken as a basis. Any blood pressure which was found to be above their 12 per cent. normal variation was regarded as high. The values given refer to systolic pressures. The diastolic pressures presented nothing of special interest.

There were, in all, ninety-eight cases of hypertension found among the 381 lead workers examined. The age distribution and the relation to

duration of employment were correlated with blood pressure just as they were with arteriosclerosis. Among the 154 workers who were 30 years old or under, the incidence of hypertension was 28.5 per cent.; among the 227 workers who were over 30 years of age, it was only 23.7 per cent. Since hypertension normally increases with advancing years, as a result of an accompanying arteriosclerosis, the fact that the incidence in the younger group was found to exceed that in the older group is of especial interest.

In order to eliminate from the picture the factor of arteriosclerosis, of whatever etiology, since it introduces a serious complication, cases of hypertension with an accompanying arteriosclerosis were then dropped from the series. Only those cases in which there was no apparent etiology for the high blood pressure, except possibly exposure to lead, were then analyzed as a separate group. When this was done, it was found that there were sixty-six workers in all who had hypertension unaccompanied by arteriosclerosis. Thirty-five of these workers were 30 years old or under, constituting approximately 22.7 per cent. of the total number of workers in that age group; while thirty-one of them were over 30 years of age, constituting approximately 14 per cent. of the total number of workers in that age group. Apparently when cases with coexisting arteriosclerosis were eliminated from the picture, the discrepancy between the incidences of hypertension in the two age groups was further increased. The much higher incidence of hypertension among the younger workers is striking. (It should be mentioned in this connection that the hypertension in this group was not usually more than 10 points above the 12 per cent. limit permitted by the Metropolitan Life Insurance Company.)

If these cases are to be regarded as probably due to lead absorption,

TABLE 5.—INCIDENCE OF HYPERTENSION IN 381 LEAD WORKERS CLASSIFIED BY AGE GROUPS

AGE GROUP *yrs.*	TOTAL IN GROUP	CASES OF HYPERTENSION	
		Number	Per Cent.
Under 16	1	1	100.0
16–18	16	6	37.5
19–21	29	7	24.1
22–30	108	30	27.7
31–40	116	24	20.6
41–50	66	13	19.6
51–60	27	9	33.3
Over 60	18	8	44.4
Total.....	381	98	25.7

TABLE 6.—INCIDENCE OF HYPERTENSION IN 381 LEAD WORKERS CLASSIFIED ACCORDING TO DURATION OF EXPOSURE

DURATION OF EXPOSURE	TOTAL IN GROUP	CASES OF HYPERTENSION	
		Number	Per Cent.
Under 2 mos.	28	4	14.2
2–6 "	57	13	22.8
7–11 "	21	3	14.2
1–2 yrs.	72	17	23.6
3–5 "	86	21	24.4
6–10 "	36	9	25.0
11–15 "	28	9	32.1
16–20 "	19	8	42.1
21–30 "	25	6	24.0
Over 30 "	9	8	88.8
Total.....	381	98	25.7

the reason for the association between increased blood pressure (in the absence of a primary arteriosclerosis) and exposure to lead becomes a matter of speculation. The theory suggests itself that possibly, just as there is a constriction of the capillaries of the face causing the characteristic pallor of lead workers, there might also perhaps be a more extensive capillary constriction throughout the body. If sufficiently extensive, this constriction of the capillary circulation could, of course, cause a slight hypertension such as was found in these workers. Such an interpretation would help to explain also the alternate rise and fall in blood pressure in lead workers from time to time, and especially in the first year, as reported by Oliver. To this end, these workers were investigated for coexistence of pallor.

Of the sixty-six workers under consideration with hypertension (and no arteriosclerosis), fourteen showed pallor, giving a percentage of 21. Of the 283 workers who had *no* hypertension, 13 per cent. showed pallor. Because of the possible association of a neurovascular constriction of the capillary circulation causing pallor with lead intoxication, these cases were analyzed further for the presence of active lead absorption as manifested by laboratory analyses of blood and urine. The incidence of lead absorption in the cases with hypertension was 68 per cent., whereas in the cases without hypertension it was 59 per cent.

Thus, while there is nothing overwhelmingly conclusive in these figures, it does seem as though there may *possibly* be some relationship between the action of the lead on the neurovascular system and the hypertension which is found among these lead workers. Pallor and lead absorption both appear to be somewhat more frequent among those having hypertension (without arteriosclerosis) than among those who have *no* hypertension. Although these differences are not sufficiently great to warrant definite conclusions at this time, they present an interesting speculation. Further study of the interrelationship of these factors would be of considerable interest.

Conclusions

1. Standardization of Terminology.—For purposes of the present discussion the term "lead absorption" has been arbitrarily reserved to describe all cases in which there is laboratory evidence that lead is being actively absorbed, as well as those cases in which the presence of the lead line demonstrates that lead had been absorbed at some previous time. This is done quite regardless of whether or not these cases give clinical manifestations of the disease. The term "lead poisoning" has been applied to those cases of "lead absorption" presenting toxic episodes such as acute lead colic, lead palsy, or lead encephalopathy. It is believed that, were this terminology generally accepted, much would be accomplished in the direction of standardizing the diagnosis of this disease. The urgent need for standardization of diagnosis is discussed.

2. Lead Line in the Gums.—The typical lead line is frequently very difficult to demonstrate in a lead worker, and must be carefully dif-

ferentiated from blueness in the gums due to cyanosis. In cases where this lead line is present, considerable care must be exercised in order to determine whether it is the result of active lead absorption at the time it is observed, or whether it merely represents a storage of lead sulphide in the gums which had been deposited there at some previous time and which is, at the time it is observed, inert. Cases of lead absorption apparently may or may not present a lead line. Careful laboratory examinations both of blood and of urine are required for a proper interpretation of the significance of the lead line in any given case.

3. Arteriosclerosis.—Of the 381 workers examined, eighty-six, or 22.5 per cent., had arteriosclerosis. All of these cases, however, occurred in men over 30 years of age, so that the actual percentage of arteriosclerosis based on the 227 men of this age group was in reality 37.8 per cent. Taking into account such factors as age, duration of exposure, and alcoholism, the present investigation would seem to show two things: (1) that the incidence of arteriosclerosis is relatively high among *all* workers of the social and economic classes from which lead workers are recruited; (2) that the part which prolonged exposure to lead plays in the production of this arteriosclerosis is questionable.

4. Hypertension.—Among the 381 cases examined, there were 98 cases of hypertension. Of the 154 workers who were 30 years old or under, 44, or 28.5 per cent., had hypertension. Of the 227 workers who were over 30 years of age, 54, or 23.7 per cent., had hypertension. Eliminating all cases having a coexisting arteriosclerosis, however, it was found that the percentage of hypertension was 22.7 per cent. in the younger group and 14 per cent. in the older group. The possible relationship between hypertension and neurovascular constriction of the capillary circulation, as evidenced by pallor, was investigated. It was thought that the existence of such a relationship might account for the fluctuations in blood pressure which had been observed in lead workers and reported by Oliver. Pallor and active lead absorption both appeared to be somewhat more frequent among those workers having hypertension (without accompanying arteriosclerosis) than among those who had no hypertension. It is felt that further study of the correlations between these factors in a larger series of cases would be of considerable interest.

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THE COMFORT ZONE FOR MEN AT REST AND STRIPPED TO THE WAIST*

C. P. YAGLOU

Department of Ventilation and Illumination,
Harvard School of Public Health, Boston, Mass.

INTRODUCTION

THE principal object of this study was to determine experimentally the comfort zone for men at rest and stripped to the waist. Such information can be applied to industries where workmen often remove all clothing above the waist. It has a wider interest as well, because it brings out the influence of clothing and also of acclimatization on the seasonal variation in the optimum temperature.

Our sensations of comfort, so far as the warmth of the atmosphere is concerned, are not fixed; they vary considerably according to (*a*) the activity of the individual, (*b*) the kind and amount of clothing worn, (*c*) the seasonal variation in weather, and (*d*) the kind and amount of food consumed. On account of these variables, it is impossible to fix a single temperature as a standard of comfort that will hold under all conditions. To solve our problem, therefore, we must determine a temperature zone which will be wide enough to include the effect of these variables. We must also determine the degree of comfort experienced by the majority of individuals at different temperature conditions within the zone.

Other Investigations on Determining the Comfort Zone

Four years ago, the Research Laboratory of the American Society of Heating and Ventilating Engineers, in co-operation with the Pittsburgh Experiment Station of the United States Bureau of Mines, established a comfort zone for men at rest wearing ordinary winter indoor clothes (1). This zone was intended to apply to average American men and women living inside the broad geographic belt across the United States in which central heating is a household necessity for from four to seven months in the year. The chief difference between the earlier work in Pittsburgh and the experiments here described consists in the amount of clothing worn by the subjects.

Vernon and his collaborators are engaged in somewhat similar work in British factories, using the kata-thermometer as an index of the thermal condition of the atmosphere. They propose to establish an empirical relationship between objective indications of the kata-thermometer and subjective sensations produced by air movements. Published data (2, p. 39)

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(3, p. 396) show the importance of regarding cooling power in relation to comfort as a variable quantity. According to Vernon (2, p. 41), cooling power varies from 5 millicalories per square centimeter per second in summer to 7 or more in winter, depending on acclimatization.

Mention should also be made of the work of the Chicago Commission on Ventilation (4) and the New York State Commission on Ventilation (5) in studying the comfort of schoolchildren in relation to temperature and humidity.

Equipment

The present experiments were conducted in the psychrometric chamber of the Department of Ventilation and Illumination, Harvard School of Public Health. A modern air conditioning equipment installed in a room adjoining the psychrometric chamber furnishes air conditioned to the desired temperature and humidity. This installation makes it possible to produce and maintain any desired atmospheric condition in the psychrometric chamber.

The psychrometric chamber and the air conditioning equipment of this School have been fully described elsewhere (6). Since then, however, we have added two plenum diffusers near the ceiling of the psychrometric room, which discharge the conditioned air uniformly and with a minimum amount of air movement.

Experimental Procedure

The experiments were begun early in November, 1925, and continued to about the middle of March, 1926. During this period, sixteen tests were made which yielded a total of 2,976 opinions on sensations of comfort. In eight of the tests, the relative humidity was maintained at 30 per cent.; in the other eight, at 70 per cent. Most of the experiments took place in the afternoon and lasted from two and one-quarter to four hours.

Eighty-five men participated as subjects. Not all of them, however, took part in all experiments. About two-thirds were students at the Harvard Medical School and their ages ranged from 20 to 32 years. The remaining one-third were drawn from the teaching staff and the employees of the School. Their ages varied from 29 to 55 years.

In order to verify the comfort zone in warm weather, we conducted two special experiments in the middle of July, 1926. In the same month we made three other tests with subjects of both sexes who wore ordinary warm weather clothing. The data from these experiments are treated separately in discussing the results.

Fresh air from out of doors was conditioned to the desired temperature and humidity and was admitted into the room at a rate of about 80 cubic feet per person per minute. Readings of dry and wet bulb temperatures were taken every ten minutes with a sling psychrometer at two representative points in the breathing zone. The air movement in the room was determined by dry kata-thermometer readings; the results showed that it varied from about 10 to 20 feet a minute.

The subjects stripped to the waist before entering the test chamber. In

the chamber they sat comfortably in chairs and read, wrote, or conversed. Every ten minutes they were asked to express their sensations of warmth according to the following scale:

1. Cold.
2. Comfortably cool.
3. Very comfortable.
4. Comfortably warm.
5. Too warm.

In the first part of the experiments, the subjects were exposed for some time to a constant temperature until their votes became consistent. The time required to accomplish this was between half an hour and three-quarters of an hour, depending on the environmental temperature to which the subjects were exposed before entering the test chamber. The votes collected during this period are not included in the analysis of the results; nevertheless, they are of some value because they show adaptation to changes in temperature.

In the latter part of the experiments, the humidity was kept constant, as in the first part, but the temperature was made to vary, usually in steps of 2° or 3° at a time. At every step the temperature was maintained until the subjects voted consistently.

In order to study the influence of humidity on comfort, the experiments were divided into two groups; in one group the relative humidity was constant at 30 per cent., and in the other it was constant at 70 per cent.

Figure 1 shows the manner in which the experiments were carried out. The diagonal lines A-B and C-D represent the 30 and 70 per cent. relative humidity lines, respectively. Area ABDC represents the probable comfort zone. The line E-F separates the cool region of the zone on the left from the warm region on the right. It may be considered to represent the probable optimum conditions for the majority. (These values were first determined roughly from preliminary experiments.) It will be seen that the cold and the warm boundaries and the probable comfort line were approached from both directions, as shown by the arrows. This was done in order to take into account the diurnal changes in adaptation to atmospheric conditions.[1] Each of the arrows represents duplicate experiments combined into one, indicating the range of temperature covered and whether the comfort line was approached from the warm or from the cool region of the zone. This gave us eight series of experiments in all.

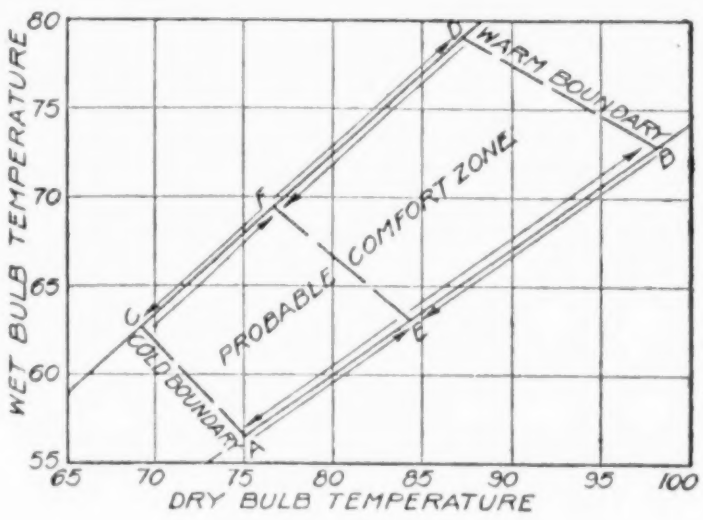

FIG. 1.—Manner in which test room conditions were varied in determining comfort zone.

Diagonal lines A–B and C–D represent 30 and 70 per cent. relative humidity lines, respectively. Area ABDC represents probable comfort zone. Line E–F separates cool region of zone on left from warm region on right.

[1] This is sometimes referred to as "changes in acclimatization."

Advantages and Disadvantages of Experimental Method

One disadvantage in our experimental method is the artificiality of the conditions. The experiments were carried out in an insulated chamber with no windows; the lighting was artificial and the air was mechanically treated.

On the other hand, the method has very distinct advantages; for the data can be secured under accurately controlled conditions, and wide variations in temperature, humidity, and air movement can be studied.

TABLE 1.—SENSATIONS OF COMFORT IN AIR CONDITIONS OF DIFFERENT EFFECTIVE TEMPERATURES

(Relative humidity 30 per cent.)

EFFECTIVE TEMPERATURE (°F.)	66–67	67–68	68–69	69–70	70–71	71–72	72–73	73–74	74–75	75–76	76–77	77–78	78–79	79–80	80–81	81–82	82–83	83–84
Increasing Temperature																		
Number of Votes Recorded:																		
1. Cold	31	28	20	13	9	5	2	..	..	..	..	..	..	..	..	..	..	..
2. Comfortably cool	6	7	7	11	13	9	5	1	..	..	..	..	..	..	..	..	..	..
3. Very comfortable	1	3	11	7	9	16	18	16	11	2	1	..	..	..	..	..	..	..
4. Comfortably warm	..	..	..	6	7	8	10	14	14	15	16	7	1	..	..	..	..	..
5. Very warm	..	..	..	..	..	..	3	8	13	21	21	21	27	28	28	28	28	28
Totals	38	38	38	37	38	38	38	39	38	38	38	28	28	28	28	28	28	28
Decreasing Temperature																		
Number of Votes Recorded:																		
1. Cold	31	22	14	7	2	1	1	..	..	..	..	..	..	..	..	..	..	..
2. Comfortably cool	4	8	7	15	16	15	11	6	4	2	1	..	..	..	..	..	..	..
3. Very comfortable	2	7	15	15	17	18	20	20	29	20	13	10	3	1	..	..	..	..
4. Comfortably warm	..	..	1	..	2	4	5	10	17	20	18	16	9	6	4	2	1	..
5. Very warm	..	..	..	..	..	..	..	2	10	17	17	23	33	41	44	46	47	48
Totals	37	37	37	37	37	38	37	38	60	59	49	49	45	48	48	48	48	48

Experimental Data

The experimental data are given in Table 1 and Table 2. In order to simplify the analysis, the dry and wet bulb temperatures are combined into the effective temperature index[2] (7) (8) (9). Table 1 contains the data secured when the relative humidity in the test room was maintained at 30 per cent. In the upper part are grouped the subjective sensations recorded with increasing room temperature, and in the lower part those recorded with decreasing temperature.

[2] Effective temperature is an index of the degree of warmth or cold felt by the human body as a result of temperature, humidity, and movement of the air. When the dry and wet bulb temperatures and the rate of air movement are known, the effective temperature can be computed from charts (Fig. 7) or tables. This index was determined experimentally at the Research Laboratory of the American Society of Heating and Ventilating Engineers (cited in (7) (8) (9)).

Table 2 gives similar data secured when the relative humidity was 70 per cent.

Sensations of Comfort in Relation to Effective Temperature and Relative Humidity

In analyzing the results, let us first compare the data obtained with the two different humidities. In Figures 2 and 3 the comfort votes, expressed in percentage, are plotted against effective temperature.

Beginning with the lowest temperature, 66.5° in Figure 2, 83 per cent. of the subjects found this condition cold, 13 per cent. said it was comfortably cool, and 4 per cent. pronounced it very comfortable. As the temperature increased, the condition became more and more comfortable until an effective temperature of 72.5° was reached. At this point, 4 per cent. of the subjects were still cold, 21 per cent. were comfortably cool, 51 per cent. very comfortable, 20 per cent. comfortably warm, and 4 per cent. very warm. If we combine the votes of graphs 2, 3, and 4, we obtain graph 6, which reaches its peak at about the same temperature, 72.5°. This temperature may be regarded as the average optimum for our subjects when the relative humidity is 30 per cent. As the temperature increased further, the condition became less comfortable, until, at an effective temperature of 83.5°, the subjects unanimously agreed that they felt too warm.

Figure 3 is very similar to Figure 2. The optimum temperature is not well defined here, but it lies somewhere

TABLE 2.—SENSATIONS OF COMFORT IN AIR CONDITIONS OF DIFFERENT EFFECTIVE TEMPERATURES

(*Relative humidity 70 per cent.*)

EFFECTIVE TEMPERATURE (°F.)	66–67	67–68	68–69	69–70	70–71	71–72	72–73	73–74	74–75	75–76	76–77	77–78	78–79	79–80	80–81	81–82	82–83	83–84
Increasing Temperature																		
Number of Votes Recorded:																		
1. Cold	31	28	22	28	14	6	4	..	..	..	..	..	..	..	..	..	..	..
2. Comfortably cool	3	6	12	16	20	24	16	4	2	..	..	..	..	..	..	..	..	..
3. Very comfortable	..	..	..	12	22	26	26	26	26	18	16	6	4	4	2	..	..	..
4. Comfortably warm	..	..	..	..	..	..	12	22	24	22	18	10	10	8	6	..	..	..
5. Very warm	..	..	..	..	..	..	..	8	10	20	30	20	26	30	28	36	36	36
Totals	34	34	34	56	56	56	58	60	62	60	64	36	40	42	36	36	36	36
Decreasing Temperature																		
Number of Votes Recorded:																		
1. Cold	34	30	24	20	18	16	8	2	..	..	..	..	..	..	..	..	..	..
2. Comfortably cool	2	6	12	14	8	14	12	14	10	6	2	..	..	..	..	..	..	..
3. Very comfortable	..	..	..	8	10	26	40	42	16	24	12	10	4	..	..	..	..	..
4. Comfortably warm	..	..	..	..	..	2	4	8	4	16	14	18	14	10	2	..	..	..
5. Very warm	..	..	..	..	..	..	..	..	4	4	6	14	14	22	30	32	32	32
Totals	36	36	36	42	36	58	64	66	34	50	34	42	32	32	32	32	32	32

between 72.5° and 73.5°, as compared with 72.5° in Figure 2. It is difficult to say whether this slight difference in optimum temperature can be attributed to the difference in relative humidity. It should be made clear, however, that our experimental data as well as our method of analysis are subject to an error of about ± ½°. The effective temperature index also involves an error of about the same magnitude. Judging from other irregularities in the graphs, it would seem more reasonable to assume that this small difference is due to experimental error, and that our sensations of comfort follow closely the scale of effective temperature.

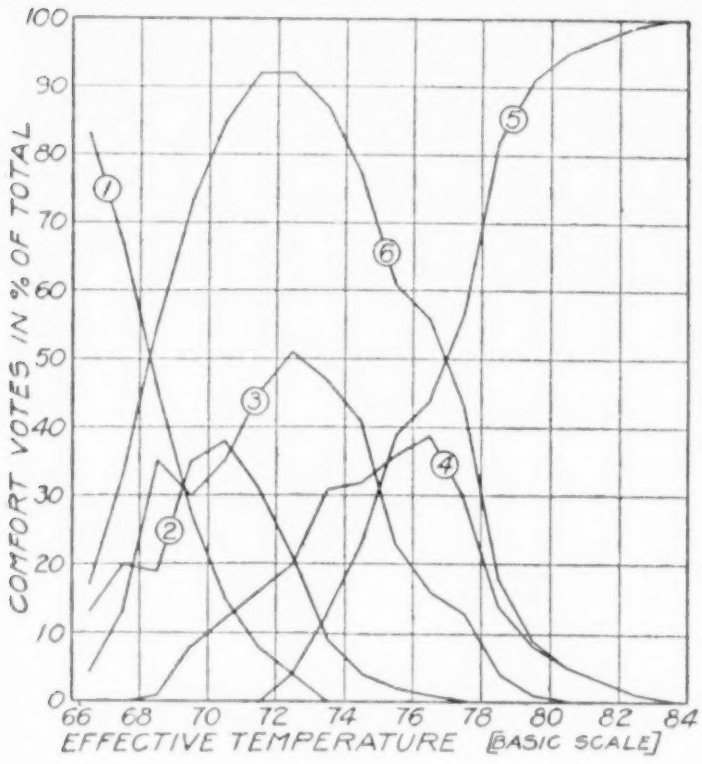

FIG. 2.—Correlation of sensations of comfort with effective temperature. Observations with 30 per cent. relative humidity.
1=cold; 2=comfortably cool; 3=very comfortable; 4=comfortably warm; 5=too warm; 6=sum of 2, 3, and 4.

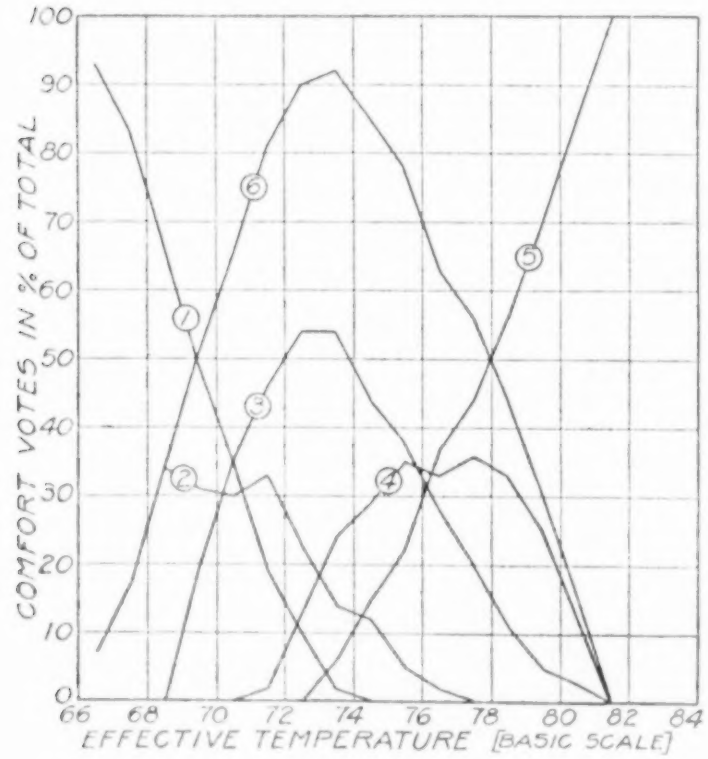

FIG. 3.—Correlation of sensations of comfort with effective temperature. Observations with 70 per cent. relative humidity.
1, 2, etc., as in Figure 2.

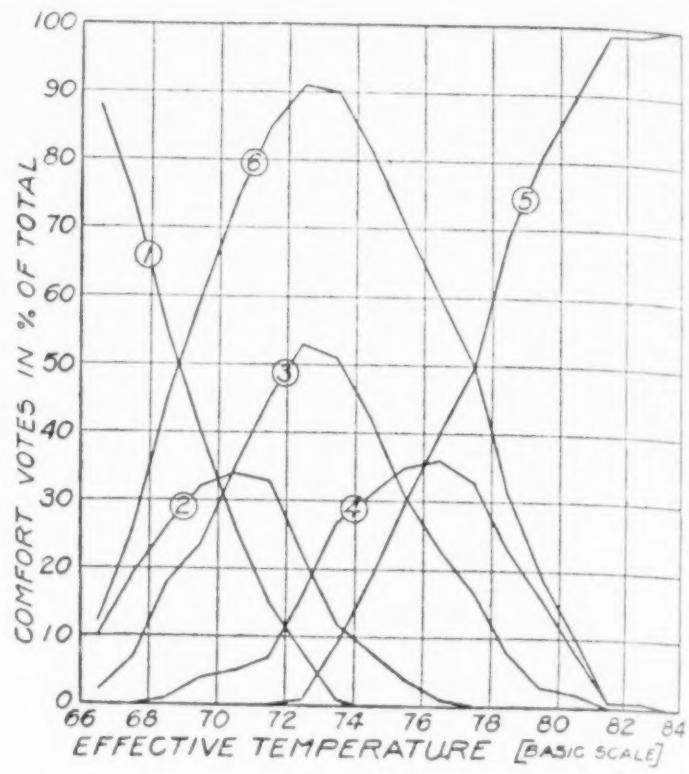

FIG. 4.—Correlation of sensations of comfort with effective temperature. Summation of data in Figures 2 and 3.
1, 2, etc., as in Figure 2.

The peak value of graph 3 in Figure 2 is 51 per cent.; the corresponding value in Figure 3 is 54 per cent. If this difference is of any significance, a humidity of 70 per cent. would seem to be slightly preferable to one of 30 per cent. Yet an examination of the Pittsburgh experiments (1), in which the subjects were normally clothed, discloses a variation in just the opposite direction.

Figure 4 shows the combined data of both humidities. The graphs are

more regular than those in Figures 2 and 3, because the number of observations is practically doubled. From these composite data, we can fix the limits of the comfort zone and determine the optimum temperature. By extrapolation we find that the cold limit of the zone falls at an effective temperature of 66° and the warm limit at 82°. The width of the zone is 16°. The optimum temperature for the majority is 72.5°, which does not fall in the middle of the zone but is nearer the cold limit. This shows that our sensations of comfort follow closely an asymmetric or skewed frequency curve. The skewness may be caused by increased perspiration in the warm region of the zone, the evaporation of which keeps the body cool and renders it less sensitive to temperature variations above the optimum than to those below.

It should be noticed that the zone given here includes all the subjects who took part in the experiment; it is therefore much wider than the comfort zone determined at Pittsburgh (1, p. 375) for men at rest and normally clothed. The Pittsburgh zone was based upon the majority opinion of the subjects and included only the average conditions of comfort. From Figure 4, we find that the corresponding average conditions for men at rest and stripped to the waist are included between effective temperature limits of 69° and 77.5°. The width of this average zone is 8.5°, or about one-half that of the entire zone.

Effect of Diurnal and Seasonal Acclimatization on Sensations of Comfort

In the first part of each experiment, we secured data which showed man's adaptation to the temperature conditions in the test chamber after entering from an environment of different temperature. In one experiment (that of Feb. 23, 1926) the temperature and humidity in the chamber were kept constant for two hours after the subjects entered. On that day the out-of-door temperature was 24°F. and the humidity 38 per cent. The temperature in the room where the subjects undressed was 69°F. and that in the test chamber 74.2°.

Table 3 shows the changes in sensations experienced by the subjects during the time of exposure. Immediately after entering the chamber, they recorded their first sensation. These first observations are of little significance so far as the comfort of the chamber is concerned, because the subjects were influenced largely by their preceding environments. In the course of the first half hour, however, they adapted themselves to the new condition and voted consistently thereafter.

It is interesting to notice that the sensations of comfort of three of the subjects did not change at all. The others changed slightly. Subject 8 showed the greatest change—from comfortably warm when he entered to comfortably cool after forty minutes. On questioning him, we found that he had walked briskly for several blocks in order to be in time for the experiment. Under the conditions which held in these experiments, our results indicate that, if the subjects are exposed to the same temperature conditions for about forty-five minutes, the influence of preceding environments appears to cease.

To ascertain whether our experi-

mental method takes account of diurnal changes in adaptation to atmospheric conditions, we divided the data into two groups. In Figure 5, all the data obtained with increasing and those of the winter is that the trousers worn in summer by the subjects were lighter than those worn in winter. This is of slight significance, however, because our sensations of

TABLE 3.—ADAPTATION TO TEMPERATURE IN RELATION TO SENSATIONS OF COMFORT[1]

(Test room conditions: dry bulb, 74.2°; wet bulb, 67°; relative humidity, 69 per cent.; effective temperature, 70.1°. Subjects entered from an environment of 69° dry bulb.)

SUBJECT NUMBER	TIME (P.M.)											
	1:55	2:05	2:15	2:25	2:35	2:45	2:55	3:05	3:15	3:25	3:35	3:50
1	V C	C C	C C	C C	C C	V C	C C	C C	C C	C C	C C	C C
2	V C	V C	V C	V C	V C	V C	V C	V C	V C	V C	V C	V C
3	C C	C C	C	C	C	C	C	C	C	C	C	C
4	C	C C	C C	C C	C C	C C	V C	C C	C C	C C	C C	C C
5	C	C	C C	C C	C C	C C	C C	C C	C C	C C	C C	C C
6	V C	V C	V C	VC	V C	V C	V C	V C	V C	V C	V C	V C
7	C C	C C	C	C	C	C	C	C	C	C	C	C
8	C W	C W	V C	V C	C C	C C	C C	C C	C C	C C	C C	C C
9	V C	C C	C C	C	C	C	C	C	C	C	C	C
10	V C	C C	C	C	C	C	C	C	C	C	C	C
11	V C	V C	V C	V C	V C	V C	V C	V C	V C	V C	V C	V C
12	V C	C C	V C	V C	V C	V C	V C	V C	V C	V C	V C	V C
13	V C	V C	V C	C W	C W	C W	C W	V C	C W	C W	C W	C W

[1] C = cold; C C = comfortably cool; V C = very comfortable; C W = comfortably warm.

temperature are plotted and, in Figure 6, all those obtained with decreasing temperature. It will be seen that there is little difference in the results from the two groups. Since the variation is well within the limits of experimental error, we may assume that due account has been taken of diurnal acclimatization.

In order to determine the effect of seasonal changes in adaptation to climate on the comfort zone, we conducted two special experiments in the middle of July, 1926. The temperature out of doors varied from 85° to 91° on the two days. Another difference, besides the outdoor temperature, between these summer experiments

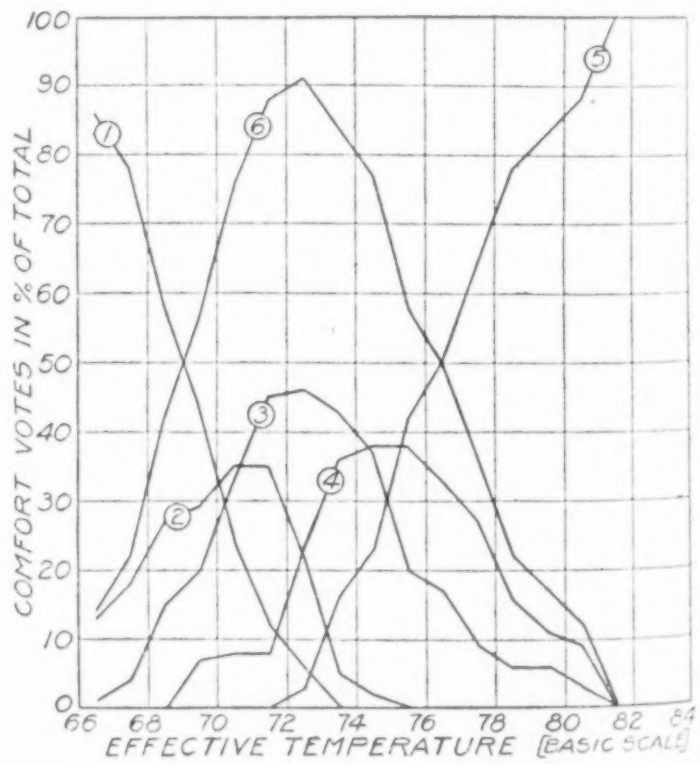

FIG. 5.—Correlation of sensations of comfort with effective temperature. Observations with increasing temperature. 1, 2, etc., as in Figure 2.

comfort are largely influenced by the upper half of the body. The optimum

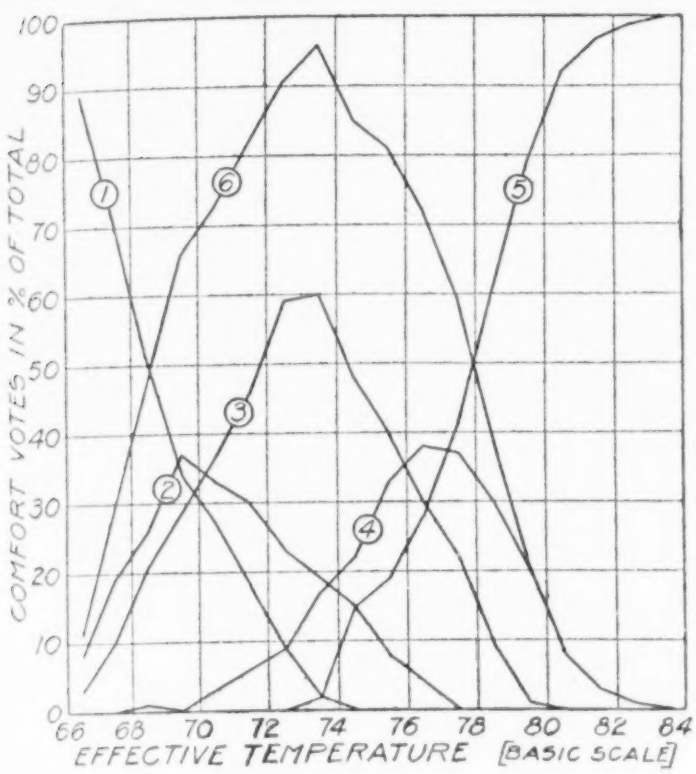

FIG. 6.—Correlation of sensations of comfort with effective temperature. Observations with decreasing temperature. 1, 2, etc., as in Figure 2.

temperature in these summer experiments was found to be about the same as it was in those conducted in winter. In other words, we failed to detect evidence of seasonal acclimatization.

Although one should not be hasty in drawing conclusions from the very limited data which we obtained in the summer, it is safe to say that, under the conditions which held in these experiments, the effects of seasonal changes in adaptation to climate are not great. Vernon found by kata (3, p. 398) that in a factory which was properly heated in winter there was practically no evidence of seasonal acclimatization.

Effect of Clothing on Temperature Limits of Comfort Zone

The influence of clothing on the limits of the comfort zone and on the optimum temperature can be studied by comparing the zone determined at the Pittsburgh laboratory for people at rest and normally clothed (1) with this zone for men at rest and stripped to the waist. The two are directly comparable except that the Pittsburgh experiments included subjects of both sexes, whereas all of our subjects were men.

The zones are compared in Table 4 on the basis of dry bulb temperature and a relative humidity of 50 per cent. It will be observed that a temperature of 70° is required for comfort when ordinary indoor winter clothing is worn; with men stripped to the waist, the temperature must be increased to 80°. The upper and lower temperature limits of the zone also differ by about 10°.

Seasonal Variation in Optimum Temperature for Comfort

In order to obtain an idea of the optimum temperature in summer for people at rest and wearing ordinary warm weather clothing, we conducted three more experiments in the latter part of July, 1926. The subjects, twenty in all, were men and women between the ages of 20 and 40 years. The temperature out of doors varied from 83° to 92° during the experiments and the humidity in the test chamber was maintained at 50 per cent. Under these conditions, the most probable optimum temperature was found to be 75.7°. In Table 5, this value is compared with that found in winter when the subjects wore winter clothing, and with that found in winter and in summer when the subjects were stripped to the waist.

It will be observed that seasonal changes in clothing, probably in asso-

ciation with seasonal changes in adaptation to climatic conditions, affect our sensations of comfort so that the optimum temperature of 70° in winter is increased to about 76° in summer.

Vernon (2) arrives at the same general conclusion. He states (p. 57): "... to produce a given sensation of air movement in winter required a cooling power about one unit higher than that required in summer. *This was due to acclimatization,*[3] and the mean cooling power (in relation to a given sensation) was found to change gradually from month to month as the mean temperature changed."

If Vernon's sensations produced by air movement may be considered comparable to our sensations of comfort, as he implies (3), it appears that, in overemphasizing the importance of acclimatization, he has underestimated the influence of clothing, in spite of the fact that his paper contains an excellent discussion on this very point.

We do not intend, in this paper, to establish standards for summer comfort; but we wish to demonstrate the variation in our sensations of comfort and to show the chief factors causing this variation. These factors—clothing and acclimatization—are now

TABLE 4.—EFFECT OF CLOTHING ON TEMPERATURE LIMITS OF COMFORT ZONE

(*Relative humidity 50 per cent.*)

COMFORT ZONE LIMITS	SUBJECTIVE SENSATIONS	DRY BULB TEMPERATURE (°F.)	
		Subjects Normally Clothed (Men and Women)[1]	Subjects Stripped to Waist (All Men)
Probable lowest	Cold	62.3	72.0
Probable optimum	Very comfortable	70.0	80.0
Probable highest	Too warm	80.0	91.8

[1] According to the Pittsburgh experiments (1).

TABLE 5.—SEASONAL VARIATION IN OPTIMUM TEMPERATURE

(*Relative humidity 50 per cent.*)

SEASON	PROBABLE OPTIMUM TEMPERATURE
	°F.
Winter (winter clothing)[1]	70.0
Summer (summer clothing)	75.7
Winter and summer (stripped to the waist)	80.0

[1] According to the Pittsburgh experiments (1).

[3] Italics are mine. —C. P. Y.

being studied separately in this laboratory.

Thermometric Chart with Comfort Zone Superimposed

Figure 7 shows a reproduction of the thermometric chart for men at rest and stripped to the waist, which was devised by the writer at the Pittsburgh laboratory. We have superimposed upon it the comfort zone determined by this laboratory.

The area covered by the zone includes effective temperatures between

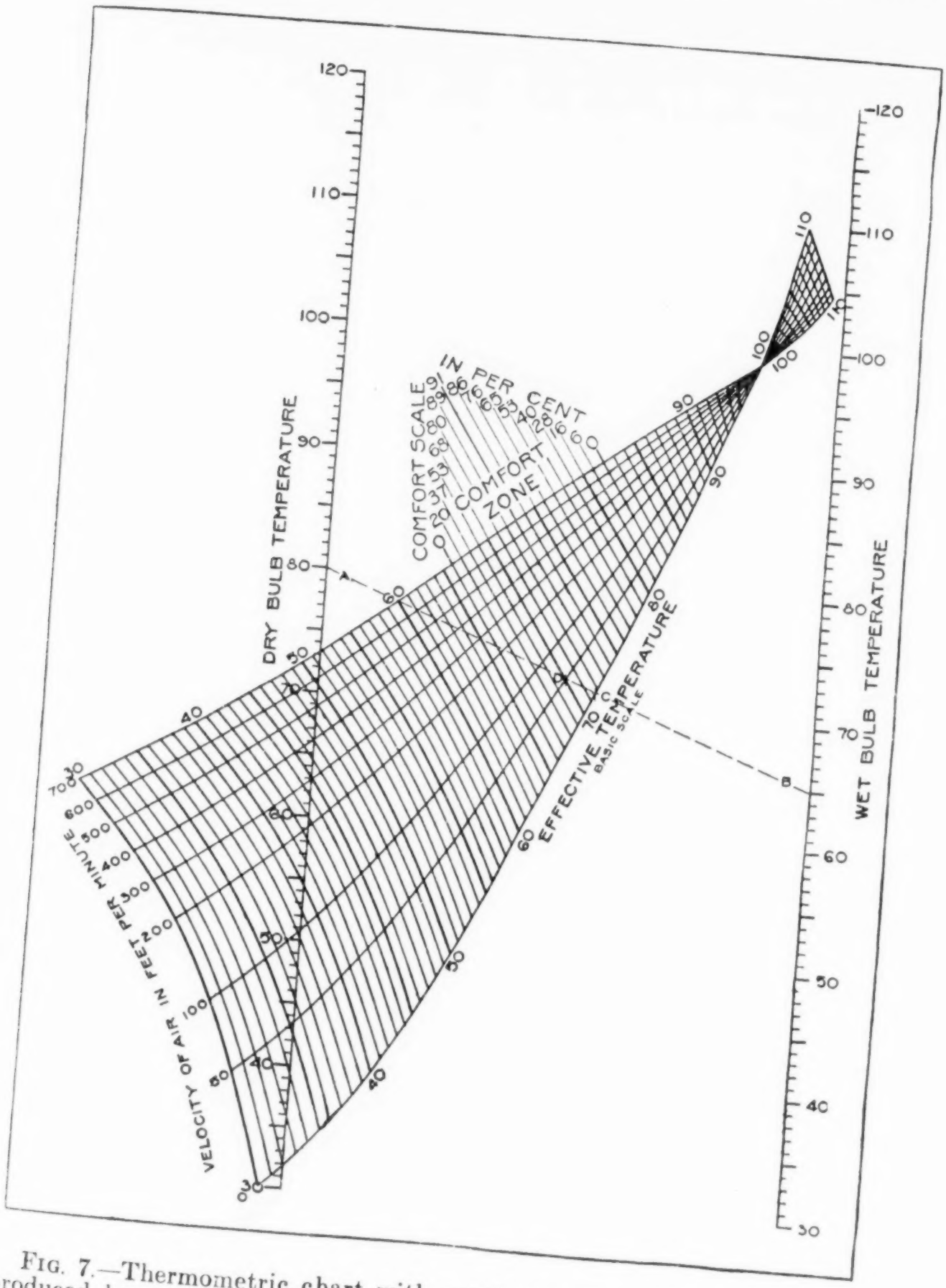

FIG. 7.—Thermometric chart with comfort zone superimposed. Reproduced by courtesy of American Society of Heating and Ventilating Engineers.

66° and 82°. The variation in the sensations of comfort within the zone is indicated. The values shown have been obtained from graph 6, Figure 4. According to these values, an effective temperature of 66° is 0 per cent. comfortable, because all the subjects found it cold; one of 73° is 91 per cent. comfortable, because it was pronounced comfortable by 91 per cent. of the subjects. These two temperatures are the limits of the cool region of the zone for the majority of people. The warm region is included between effective temperatures of 73° and 82°. For practical purposes, an effective temperature of 73° may be considered the optimum for the majority.

Although the comfort zone was determined under practically still air conditions (an air movement of 10 to 20 feet a minute), it is extended in the chart to include wind velocities up to 700 feet a minute. This was accomplished by referring to the previous findings of the Pittsburgh laboratory (10) on thermo-equivalent conditions of temperature, humidity, and air movement.

It should not be inferred, however, that conditions in the higher temperature region of the zone, which are accompanied by high rates of air movement, produce identical sensations of comfort with the thermo-equivalent conditions in the lower temperature region with mild air currents. The two are equivalent thermally, but the body is called upon to respond differently. In other words, although the heat loss from the body may be the same, the channels of heat loss are different. At the higher temperatures, sensible perspiration comes into play as an emergency outlet for the excess body heat. Such conditions, if prolonged, involve undue strain on the heat regulating center. The lower temperature region of the zone with mild air currents is much to be preferred, not only because such conditions are more comfortable and pleasant, but also because they are usually more economical to maintain. Nevertheless, where high temperatures are unavoidable, they can be most successfully alleviated by increasing the velocity of the air, so long as the environmental temperature does not exceed the temperature of the body.

Summary

The comfort zone for men at rest and stripped to the waist has been found to lie between 66° and 82° on the effective temperature scale. The most probable optimum appears to be 72.5°. These values take into consideration both diurnal and seasonal acclimatization. Diurnal changes in adaptation to atmospheric conditions were accounted for by keeping the temperature constant for one-half to three-quarters of an hour before recording the subjects' sensations of comfort. This period seemed to be sufficient to overcome the effect of previous environmental conditions in the case of men stripped to the waist. Seasonal changes in adaptation to climate were accounted for by carrying out experiments both in summer and in winter. The failure to discover evidence of seasonal acclimatization may proceed from either of two causes: The summer data may be too few, or the seasonal changes in adaptation to climate may be smaller than the experimental error.

Clothing was found to affect the comfort zone considerably. At a relative humidity of 50 per cent., the probable optimum temperature in winter was 70° dry bulb when ordinary indoor clothing was worn, and 80° dry bulb when men were stripped to the waist. When the subjects were dressed according to the season, there was a variation of about 6° dry bulb between the summer experiments at this laboratory and the winter experiments of the Pittsburgh laboratory.

This comfort zone for men at rest and stripped to the waist is superimposed upon the thermometric chart designed at the Pittsburgh laboratory. By means of this new chart, the relative comfort of ordinary atmospheric conditions can be determined when the dry and wet bulb temperatures and the velocity of the air are known.

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BOOK REVIEWS

Clinical Application of Sunlight and Artificial Radiation; Including their Physiological and Experimental Aspects with Special Reference to Tuberculosis. By *Edgar Mayer*, M.D. Cloth. Pp. xvi, 468 with appendix, bibliography, and indexes; illustrated. Baltimore: The Williams & Wilkins Co., 1926.

In spite of the restriction implied by its title, this book is of considerable value to all who are interested in the biologic action of light. Dr. Mayer has compiled a very comprehensive treatise and presents a notable contribution to light therapy. The following chapter headings afford a very good idea of the wealth of material presented: Introduction and Historical; The Nature of Radiation; Some Fundamental Considerations on the Action of Light in Animal and Plant

Life; The Action of Light on Growth and Nutrition; The Effect of Radiant Energy upon Bacteria and Related Biological Products; Physiological Action of Light; The Skin as an Organ; The Sensitisation of Tissues to Light; Some Fundamental Studies; The Influence of Climate on Solar Radiation; The Clinical Application of Solar and Aerotherapy; The Sources of Light used in Therapy; Clinical Studies with Artificial Light; The Dosage and Technique in the Clinical Use of Artificial Light; Indications and Contra-indications for Irradiation; The X-Ray Treatment of Tuberculosis.

The various chapters on the biologic action of light are especially informing and interestingly written; they will appeal alike to the layman and to the scientist. An appendix deals with the influence of light on certain biochemical reactions and is followed by an especially valuable bibliography of fifty-seven pages.—*L. T. Fairhall.*

CHILD LABOR IN MASSACHUSETTS. AN INQUIRY UNDER THE AUSPICES OF THE MASSACHUSETTS CHILD LABOR COMMITTEE. By *Raymond G. Fuller*, Author of "The Meaning of Child Labor," "Child Labor and the Constitution," etc.; and *Mabel A. Strong*, Executive Secretary, Massachusetts Child Labor Committee. Paper. Pp. 170 with appendix and index. Boston: Massachusetts Child Labor Committee, 1926.

As stated by Grafton D. Cushing in his Foreword, this inquiry "represents one of the first attempts since the defeat of the Federal Child-Labor Amendment to restate the principles underlying the reform movement and to indicate its opportunities and prospects." The scope of the reform program indicated by the authors may be summarized as including: (1) prevention of premature school leaving by measures to prevent poverty and measures to improve schools; (2) provision by parental and community effort of the substitutes for child labor, *e.g.*, suitable work, play, and schooling; (3) inculcation of higher standards of living and higher ideals of family and of community life; (4) restoration under modern conditions of the close relationship between education and occupation that subsisted when home and local community were economically self-sufficing units.

In an historical retrospect are reviewed the changing conditions during the last century that gave rise to successive legislation regarding child labor. Legislative gains relating to child labor and school attendance in Massachusetts are summarized down to the present time.

The statistical background for the present inquiry is presented clearly by tables compiled from figures of the United States Census and from still more recent figures furnished by the Massachusetts State Department of Education from the certification of minors between 1919 and 1925. These are analyzed especially (*a*) with regard to the relative amount of urban, industrial, and agricultural child employment in Massachusetts as compared with the country at large, and (*b*) with regard to the fluctuations of child employment. Figures relating to school enrollment and attendance in Massachusetts as compared with other parts of the United States are summarized from the "Biennial Survey of Education, 1920–1922," United States Bureau of Education.

A study of the most significant recent literature regarding occupations of children leads to definite conclu-

sions: (1) "Wherever these children are, it is mainly their arms and legs that are wanted;" (2) occupations of 14 to 15 year old children, with some exceptions, require little skill and offer little prospect of promotion; (3) earlier jobs often hinder later advancement; (4) in most trades children of 14 and 15 are barred out of apprenticeship by established rules approved by employers and labor unions; (5) the wages of a large proportion of working children are not continuous throughout the year; (6) in regard to children in agriculture, dangerous conditions have been found in the industrialized forms of agriculture such as prevail for example in sugar beet growing in the Middle West and in the tobacco and onion fields of western Massachusetts.

Consideration of data with regard to accident hazards shows that the accident rate is much higher for children than for adults under similar conditions. While many of the most dangerous trades in Massachusetts are closed to children, the question is raised whether the accident hazard can be reduced to an extent that will justify the employment of adolescent children at all the forms of factory employment now open to them. A need is shown for more adequate health service to children before they go to work, when they go to work, and after they go to work, in order to prevent the neglect or aggravation of physical defects. The liability in early adolescence to the development of nervous disturbances is emphasized as requiring careful attention.

The question of early school leaving in relation to child labor is analyzed in detail and current ideas in respect to the low intelligence of children leaving school early are disproved by statistics. The advantages are discussed of the substitution of the half time plan for the present four hours a week in a continuation school, for working children under 16. Valuable suggestions are made for a system to secure vocational supervision of subnormal children certified for employment. Poverty as a cause for early school leaving is discussed together with present day methods for the alleviation of poverty.

The function of child labor laws is shown to be the regulation not merely of the work itself but the prevention of its infringement upon any of the rights of childhood. Emphasis is placed on the prevention of injury not by work *as work*, but by excessive hours, improper surroundings, or work bearing no relation to the child's physical or mental capacities. The present standards with regard to child labor in Massachusetts are given in detail. With these are compared the laws of other states in respect to such provisions as are considered significant from the standpoint of improvement in the Massachusetts statutes, *e.g.*, basic age minimum, school attendance age, educational qualification, health requirement, reexamination of workers, employment certification, maximum hours of labor, continuation school attendance, and accident compensation. The legislative standards are given which have been formulated by the National Child Labor Committee as essential for incorporation in the statutes of all the states.

There is a full discussion of the two new legislative proposals before the Legislature designed to extend the present schooling opportunities for the

14 year and 15 year old children and to help correct a defect in the law relating to the physical examination of minors applying for employment certificates. These proposals are strongly endorsed, and the development of more and better health work in the continuation schools is urged.

In presenting the tasks which are still to be accomplished, the authors recommend the following for investigation and research: the situation in the tobacco and onion fields of the Connecticut Valley; the problem of vocational supervision of mentally subnormal children certified for employment; a critical study of the administration and enforcement of all the existing legislation relating to school leaving and going to work; a complete study of the economic factor in early employment; the leisure time problem for the working child. Case work methods in the administration of a child labor law are advocated and in this connection it is recommended that vocational guidance should be established as a definite service in every school system in the state. The really significant change in child labor reform "is that which sees in the future less importance for coercive and more for non-coercive techniques." The latter "are, in sum, the methods of education and guidance." "Child and education—these together are the paramount concern of child-labor reform and the indispensable means of social progress."

In the Appendix are given tables showing the occupational distribution of Massachusetts continuation school children, 1920 to 1921; the principal Massachusetts industries employing continuation school children, 1920 to 1921; the number and proportion of child employees in certain industries in Massachusetts compiled from the United States Census of 1920; lists are given of the dangerous trades forbidden by the laws of Massachusetts to children under the age of 18 and to children under the age of 16.

It is to be hoped that this volume may be read widely, since much of the widespread misunderstanding in regard to child labor reform could thereby be cleared away and greater cooperation be enlisted. It should be equally valuable to those interested in the subject of child labor in other states from the fact that it deals with problems encountered throughout the country.—*Ruth A. Davis.*